SHORELINE CHANGE ANALYSIS OF VIZHINJAM COAST USING BEACH PROFILES AND SATELLITE IMAGES

ANNUAL REPORT
(October 2018 to September 2019)

FOR

ADANI VIZHINJAM PORT PVT LIMITED

PREPARED BY

Coastal and Environmental Engineering Division

NATIONAL INSTITUTE OF OCEAN TECHNOLOGY

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Executive Summary

This report includes the study on shoreline change assessment along Vizhinjam coast about 40km stretch for the period from October 2018 to September 2019 using available high resolution satellite images and field measured beach profile data. It includes identification of high erosion zone along the study area.

In the previous Annual report for the period October 2017 to September 2018, the result from the shoreline change analysis using high resolution satellite images carried out for 2000-2018 and annual variation for the years 2015-2016, 2016-2017, 2017-18 has been presented. As a part of NGT direction, the shoreline change analysis has been carried out for the years 2000-2010, 2010-2018, 2000-2018 using high resolution LISS 4 (5m) and PAN (2.5m) images to study the changes before and after 2010. Further, the shoreline change analysis has been carried out for the years 2000-2005, 2005-2010, 2010-2015, 2015-2018 to study the immediate changes prior and after port commencement activity (December 2015). The spots of erosion listed from the above analysis using high resolution satellite images are Valliyathura (CSP63 to CSP67), Punthura (CSP53 to CSP57), Neerody to Edapadu (CSP01 to CSP09) and the same has been compared with the spots of erosion from annual shoreline analysis from October 2018 to September 2019.

Beach profile data of the entire 40km stretch from October 2018 to September 2019 has been analysed. In order to study the beach volume change in October 2018, the beach profile data of September 2018 has been considered for the analysis. The overall beach volume change shows net accretion at CSP 22-23 (Karumkulam), CSP 32-33 (Adimalathura), CSP 35-38 (Mullur), CSP 61 (Cheriyathura) and net erosion at other locations.

The zones of High erosion and accretion have been derived from the available high resolution satellite images (10m and 5m) for the months from October 2018 to September 2019 and it indicates it indicates accretion at few transects of Cheriyathura and Mullur, stable at Pannathura and Adimalathura whereas erosion is noticed at Kochuveli, Shangumugam, Valliyathura, Punthura, Pullavila to Edapadu beach. The spots of erosion have been compared with beach profile analysis and the results shows similar trend in both cases.

AVPPL has provided the monthly beach profile data collected (for the entire stretch of 40Km at 81 transect) by the surveying agency for the period from October 2018 to September 2019. These have been analyzed, QA and QC have been carried out and final data sets were made. These data sets have been used for analysis of beach changes on monthly, seasonally,

yearly and inter-annually basis which has been included in the report. In addition, NIOT has provided a wave rider buoy which is deployed/ installed and periodically maintained with the help of AVPPL and the data received by NIOT are evaluated. A summary report of the data received and modeling report for the period March 2018 to February 2019 by LNTIEL has been vetted by NIOT.

As a part of the scope of work, following reports have been submitted by NIOT:

- I Quarterly report, October 2018 to December 2018 have been submitted in 29 March 2019.
- II Quarterly report, January 2019 to March 2019 has been submitted in 07 June 2019.
- I Half-Yearly report submitted from October 2018 to March 2019 submitted in 12 June 2019.
- III Quarterly Report April 2019 to June 2019 has been submitted in 24 July 2019.
- IV Quarterly report, June 2019 to September 2019 has been submitted in November 2019.
- This final report comprising of one year study including available high resolution satellite imageries, beach profile and other related measurement has been analyzed and reported for the period October 2018 to September 2019.

1 INTRODUCTION

NIOT has been awarded the work to study shoreline change analysis along Vizhinjam coast using beach profile data and available satellite images for the period of one year from October 2018 to September 2019 by Adani Vizhinjam Port Private Limited (AVPPL), (SO No. 5700262831 dated 07/03/2019). Accordingly, NIOT has procured the latest available high resolution satellite image data from National Remote Sensing Centre (NRSC) and obtained field measured data sets (beach profile) from AVPPL to study the shoreline changes analysis for 40 km stretch along Vizhinjam coast.

Similar shoreline change study previously carried out by NIOT and the Annual Shoreline Study report for the period October 2017 to September 2018 has been submitted to Member Secretary NGT appointed committee. Subsequently, Kerala Coastal Zone Management Authority (KCZMA) has uploaded the Report on to their website.

This report consists of the study on shoreline change analysis carried out over 40 km stretch keeping Vizhinjam Port as center, using available high resolution satellite images and beach profile data for the period from October 2018 to September 2019. To study the shoreline and beach volume change in October 2018, the shoreline and beach profile data of September 2018 has been considered for the analysis.

2 OBJECTIVES

i) To assess the shoreline change over the 20 km coastline on either side Vizhinjam port using satellite images and beach profile data for the year October 2018 to September 2019.

ii) To identify the erosion and accretion hotspots using available moderate and high resolution multispectral images acquired by remote sensing satellites and Field measured beach profile data for the year October 2018 to September 2019.

iii) Vetting of reports on oceanographic, hydrographic, bathymetric field measured data and numerical model studies provided by AVPPL/VISL.

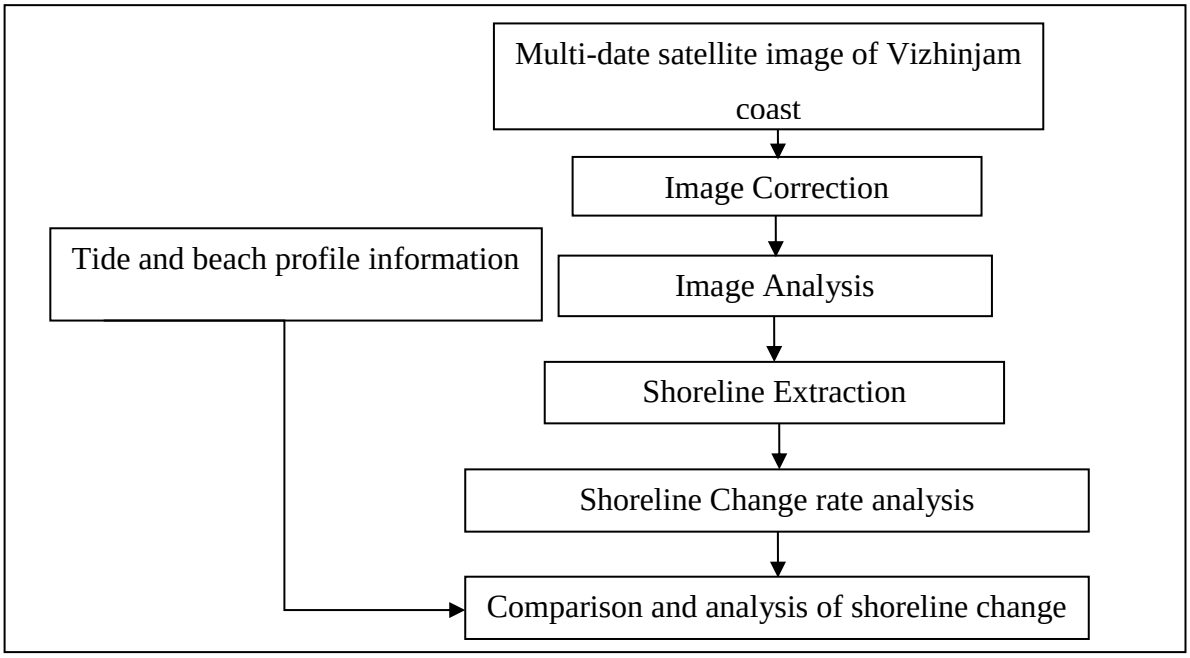
3 METHODOLOGY & DATA USED

The methodology flowchart is shown in Figure 3.1. The shoreline change analysis has been carried out using satellite images to estimate the rate of change in terms of distance eroded or accreted and the rate of change estimated using cross shore profile in terms of area and volume. From the satellite images, the shoreline has been extracted after rectification and co-registration. The shoreline change rate from October 2018 to September 2019 has been

analysed, and the trend has been compared with beach profile data. Digital shoreline change analysis system (DSAS) is a software application that works within the Geographic Information System (ArcGIS) software. DSAS computes rate-of-change statistics for a time series of shoreline vector data. It is also useful for computing rates of change for other boundary change conditions that incorporate a clearly-identified feature position at discrete times.

Similarly, the beach profile data perpendicular to the shoreline for 40 km stretch at intervals of 500m, using RTK or total station landward up to 100m distance from HTL or +2m elevation w.r.t. HTL and using shallow-draft boats, sled or any other suitable techniques seaward down to 10m CD collected monthly. The shoreline change analysis using beach profile data has been carried out using SANDS software. The detailed methodology of the shoreline change analysis using satellite images and beach profile analysis has been provided in this report.

Figure 3.1 Flowchart of the methodology adopted



3.1 Shoreline change analysis from Satellite images

3.1.1 Short Term Shoreline change analysis

The end point rate (EPR) is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline (Figure 3.2). The major advantages of the EPR are the ease of computation and minimal requirement of only two shoreline dates. The major disadvantage is that in cases where more data are available, the additional information is ignored.

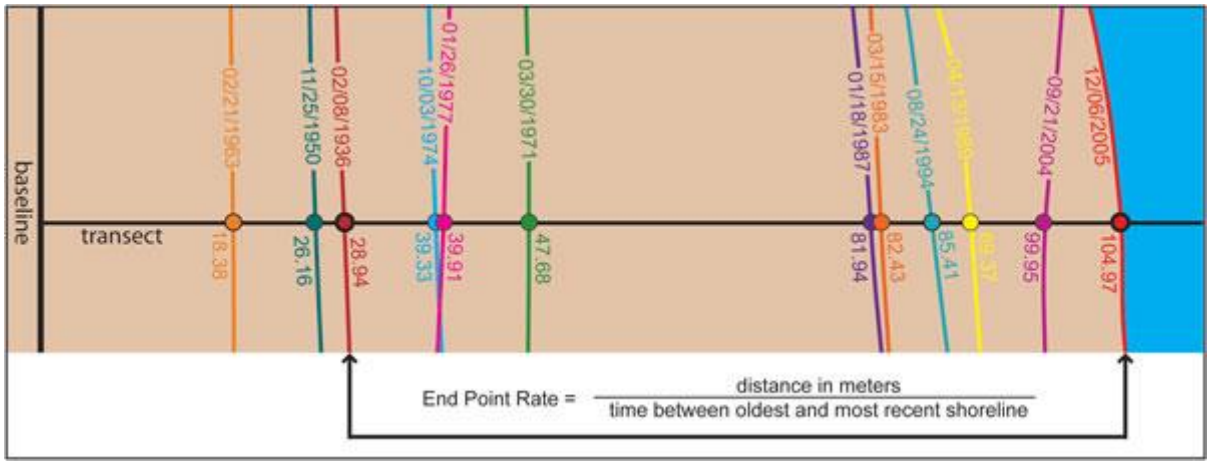


Figure 3.2 Calculation of Short Term Shoreline change analysis (Sample image source: Thieler et al., 2017)

3.1.2 Long Term Shoreline change analysis

A linear regression rate-of-change (LRR) statistic is determined by fitting a least-squares regression line to all shoreline points for a particular transect Figure 3.3. The regression line is placed so that the sum of the squared residuals (determined by squaring the offset distance of each data point from the regression line and adding the squared residuals together) is minimized. The linear regression rate is the slope of the line. However, the linear regression method is susceptible to outlier effects and also tends to underestimate the rate of change relative to other statistics.

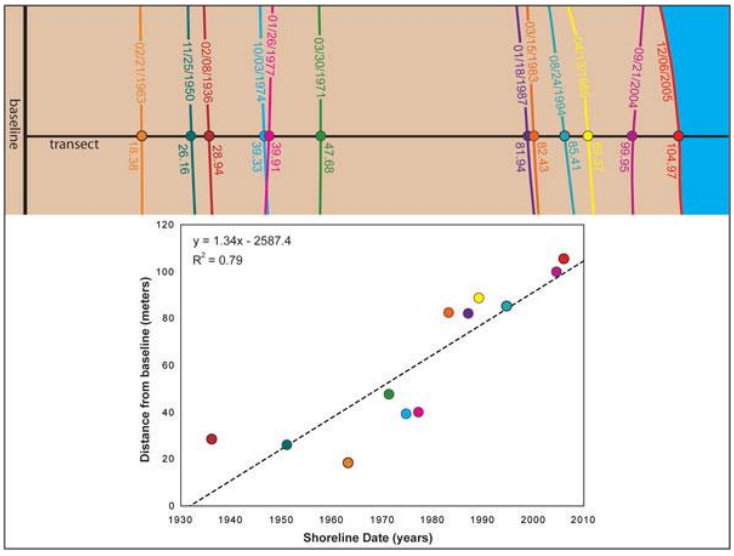


Figure 3.3 Calculation of Long Term (LRR) Shoreline change analysis (Sample image source: Thieler et al., 2017)

3.1.3 Satellite image used in shoreline change analysis

The input image has been acquired from the European Space Agency for Sentinel 2A MSI images to study monthly and seasonal change in shoreline for the period from October 2018 to September 2019. The satellite images have been co-rectified, and the available data are provided in Table 3.1. As per NGT expert and Shoreline monitoring committee recommendations, the available high resolution satellite images for the period from October 2018 to September 2019 have been procured (Table 3.2). During the study period, satellite images of 2.5 m resolution have not been procured due to non-availability of the same for the study region. The image has been geo-rectified using the field collected ground control points (GCP) during the field visit carried out during 3rd July 2018 to 5th July 2018.

Table 3.1 Satellite image data used for decadal shoreline change analysis

Satellite	Date	Sensor	Resolution (m)
SENTINEL 2A/2B	04-09-2018	MSI	10
	21-10-2018		
	10-11-2018		
	20-12-2018		
	09-01-2019		
	13-02-2019		
	05-03-2019		
	14-05-2019		
	28-06-2019		
	08-07-2019		
	02-08-2019		
	21-09-2019		

Table 3.2 Satellite image data procured from NRSC for shoreline change study

Satellite	Date	Sensor	Resolution (m)
R2A	21-09-2018	LISS4	5
	12-02-2019		
	06-07-2019		
	10-10-2019		
	08-10-2017		
C1	18-02-2018	PAN	2.5
	03-01-2015		

3.2 Beach Profile Analysis

Shoreline Change analysis using Cross shore Profile (CSP) has been done as part of the Shoreline Monitoring Programme. CSP data is being collected monthly by the surveying agency every month at 81 profile lines along a stretch of 40 km covering the area of approximately 20 km south and 20 km north of the proposed Vizhinjam port (Since February 2015 to till date). The locations of the CSP lines are shown in Figure 3.4, and the corresponding landmarks and location names are given in Table 3.3. However, due to rough sea condition along the Vizhinjam coast, offshore profiles for the months from June 2019 to August 2019 have not been collected. The offshore profiles collected for the month of September 2019 has been considered for the overall beach volume change analysis.

Figure 3.4 Beach Profiles lines

Cross Shore Profile (CSP) surveys have been carried out as two components Viz.:

(1) CSP Surveys (land part) using RTK (Real Time Kinetic) GPS System landward up to 100m distance from HTL or +2m elevation w.r.t. HTL and

(2) CSP Surveys (Sea Part) using multi-beam echo sounder system to cover 10m CD; collected monthly (4 CSP Lines to be carried out up to a depth of 20 m in the month of January, May, August and October as per shoreline committee suggestion vide MoM of meeting dated 13th February 2019).

These data sets are combined, processed and transferred to NIOT for analysis by the surveying agency.

Table 3.3 Landmark and places names around each CSP lines

CSP NOs.	LAND MARK	LOCATION
CSP-01	CATHOLIC CRISMATIC PRAYER CENTER	EDAPPADU BEACH
CSP-02		
CSP-03		
CSP-04	ST.MARYS CHURCH	VALLAVILAY
CSP-05		
CSP-06		
CSP-07	ST.NICOLAS CHURCH	NEERODY
CSP-08		
CSP-09		
CSP-10	SREE BHADRAKALI TEMPLE	POZHIYOOR
CSP-11		
CSP-12		
CSP-13	ST.MATHEWS CHURCH	PARUTHIYOOR
CSP-14	CHURCH OF CRIST	
CSP-15	POOVAR ISLAND RESORT	POOVAR BEACH SOUTH
CSP-16		
CSP-17		
CSP-18	POZHIKARA BEACH	POOVAR
CSP-19		
CSP-20	ST.ANTONYS CHAPEL	POOVAR BEACH NORTH
CSP-21		
CSP-22	ST.ANTONYS CHURH	KARUMKULAM
CSP-23		
CSP-24		
CSP-25		
CSP-26		
CSP-27	GOTHAMBU ROAD	PULLUVILA
CSP-28		
CSP-29		
CSP-30		
CSP-31	ADIMALATHURA CATHOLIC CHURCH	ADIMALATHURA
CSP-32		
CSP-33		
CSP-34		
CSP-35	AZHIMALA TEMPLE	AZHIMALA
CSP-36	NAGAR BHAGAVATHY TEMPLE	MULLUR
CSP-37		
CSP-38	ADANI RECLAMATION AREA	ADANI PORT OFFICE VIZHINJAM
CSP-39		
CSP-40		
CSP-41	VIZHINJAM LIGHT HOUSE	KOVALAM
CSP-42		
CSP-43		
CSP-44		
CSP-45		
CSP-46		
CSP-47	SAMUDRA BEACH PARK	KOVALAM (NORTH)
CSP-48	MOSQUE	PANATHURA (SOUTH)
CSP-49		
CSP-50	PANATHURA TEMPLE	PANATHURA (NORTH)
CSP-51		
CSP-52		
CSP-53	PUNTHURA FISH MARKET	PUNTHURA
CSP-54		
CSP-55		

CSP-56		
CSP-57		
CSP-58	BEEMA PALLY	BEEMA PALLY
CSP-59		
CSP-60		
CSP-61	CHERIYATHURA SPORTS GROUND	CHERIYATHURA
CSP-62		
CSP-63	VALLIYATHURA BRIDGE	VALLIYATHURA
CSP-64		
CSP-65		
CSP-66		
CSP-67		
CSP-68	SHANGUMUGHAM BEACH	SHANGUMUGHAM (SOUTH)
CSP-69		
CSP-70	ST.PETERS CHURCH	SHANGUMUGHAM (NORTH)
CSP-71		
CSP-72	VETTUCAUD CHURCH	VETTUCAUD
CSP-73		
CSP-74		
CSP-75	VELI CHILDRENS PARK	KOCHUVELI
CSP-76		
CSP-77		
CSP-78	ST.THOMAS CHURCH	VALIYA VELI
CSP-79		
CSP-80	CHRISTIAN BROTHEREN CHURCH	THUMBA
CSP-81		

The data received was analyzed by plotting each profile and using SANDS. The aim of this exercise was to establish a base data to compare profiles with surveyed data from different location for different seasons. This data shall serve to assess the beach profile after the construction of the port at Vizhinjam in future. The difference, if any, shall be investigated further to understand impact due to the port on the shoreline evolution. Profiles for different months were plotted location wise. A sample plot of the profile is shown in Figure 3.5.

A beach profile is defined as a set of beach levels taken at recorded distances in a straight line (Figure 3.5). It is accepted that beach profiles can only be of real use when surveys are taken over a period of time starting at exactly the same place and moving in exactly the same direction (the Origin and Orientation of the profile). SANDS software stores the beach profile surveys, to view them graphically and to analyse them to identify trends in beach levels at a location over time. The 'Beach Profile Graph' feature allows the user to graph and compares beach profiles from different/multiple locations.

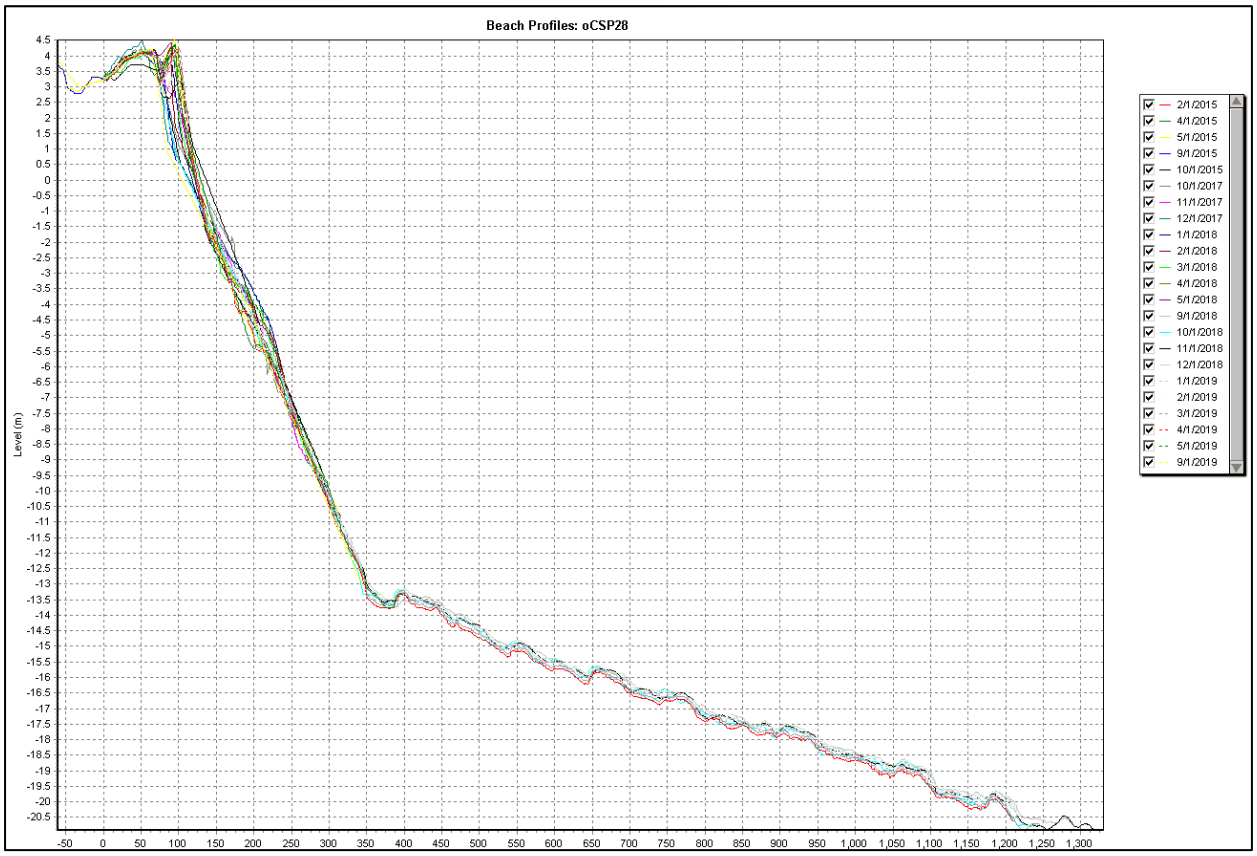


Figure 3.5 Sample beach profile graph of CSP 28 (Pullavila) using SANDS software

It was observed during the analysis of cross shore profiles that some of the profiles appeared distorted, possibly due to some errors during the survey. These profiles are either discarded or manually corrected in respect of the earlier profiles. The profiles corresponding to the Vizhinjam Port area is completely discarded and mentioned as a development zone.

The CSP data after reprocessing qualitatively and quantitatively is directly imported to SANDS for shoreline change assessment. The following flow chart (Figure 3.6) explains the process and workflow in SANDS.

Figure 3.6 Work Flow in SANDS

3.3 Analyzing Beach Profiles in SANDS

SANDS allow for any number of beach profiles survey records to be stored at each profile location over a period. This database has been used for determining the stability and long term

trends in beach levels. The two main Beach Profile Analyses are Profile Analysis by Level and Profile Analysis by Chainage.

3.3.1 Profile Analysis by Level

Profile analysis 'by Level' method analyses the changes in the chainage at which certain levels occur whilst the other analyses changes in level at certain chainages (Figure 3.7). In other words, this analysis looks at horizontal strips of the profile.

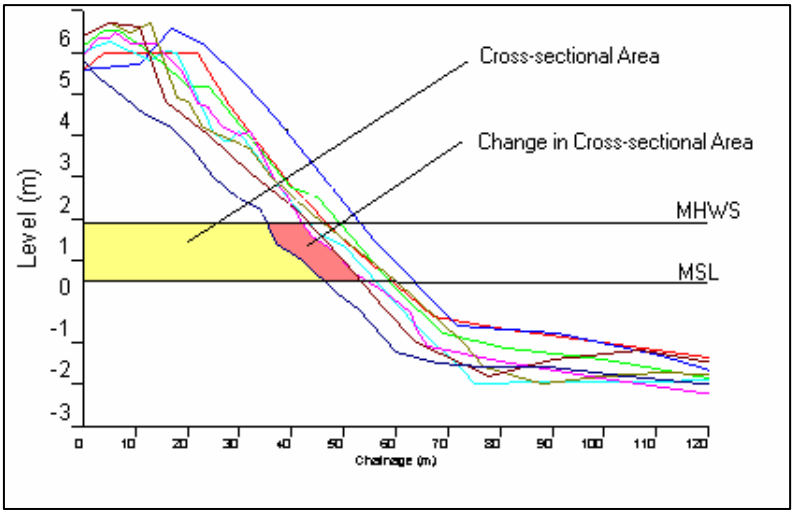


Figure 3.7 Profile Analysis by Level

3.3.2 Profile Analysis by Chainage

Profile analysis 'by Chainage' method analyses the changes in level at certain chainages whilst the other analyses changes in the chainage of certain levels. In other words, this analysis looks at vertical strips of the profile (Figure 3.8).

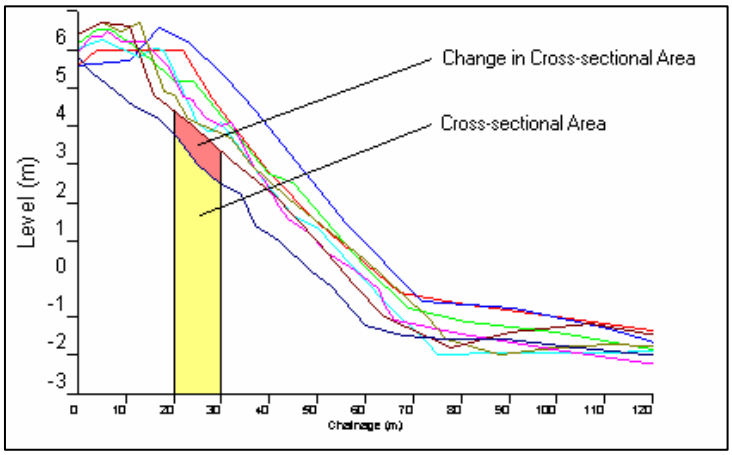


Figure 3.8 Profile Analysis by Chainage

Based on the above methods SANDS calculate the profile changes and then it calculates volumes of pre-defined areas. It also enables to group together all beach profile locations and analyze the volumes of these units. SANDS calculate the Profile Accretion / Erosion through a direct comparison between profiles over the period of comparison and allow the results to be displayed within a GIS-style plan-view format to give striking visual results.

4 RESULTS AND ANALYSIS

In the present study, the shoreline rate of change statistics from time series of multiple shoreline positions of 40 km coastal stretch of south Kerala coast (20 km either side of Vizhinjam Port) has been taken in to account for shoreline calculation using satellite images. In order to study the shoreline change in October 2018, the shoreline data of September 2018 has been considered for the analysis. The result from the shoreline change analysis carried out from October 2018 to September 2019 using 10m satellite images and 5m high resolution satellite images is presented in this report.

Hence, with the available satellite images of 10m resolution for the monthly shoreline change analysis, this classification may indicate high erosion and high accretion based on the scale followed for the same as higher resolution images. Based on the rate of change over the period, shoreline change has been categorized into 5 classes. They are high accretion (>5m/year), moderate accretion (5m to 1m/year), stable coast (1m to -1m/year), moderate erosion (-1m to -5m/year), high erosion (<-5m/year). The shoreline change analysis using high resolution satellite images for February 2018 and February 2019 have also been presented.

The observations from the beach profile analysis done using SANDS for the entire 40 km stretch has been presented as monthly, seasonal and half yearly changes in the beach volume for a period from October 2018 to September 2019. volume changes have been assessed by comparing month to month profiles and the seasonal and the overall beach volume changes. The erosion and accretion are highlighted with red and green color fill in the charts for better understanding. The results shown in the charts are also presented in the tables.

4.1 Results from Beach Profile Analysis

The beach profile data consist of both foreshore and offshore profiles. Monthly beach volume changes have been assessed by comparing month to month profiles. In the previous Annual report October 2017- September 2018, the beach volume (monthly, seasonal and

yearly) changes from February 2015 to September 2018 has been analysed and reported. In order to study the beach volume change in October 2018, the beach profile e data of September 2018 has been considered for the analysis. In continuation with the previous study, this report includes the monthly, seasonal and overall changes from October 2018 to September 2019.

4.1.1 Monthly Beach Volume variations – October 2018 to September 2019

In order to study the beach volume change in October 2018, the beach profile data of September 2018 has been considered for the analysis. The changes in every month (October 2018 to May 2019) and overall beach volume changes (September 2019 has been considered for the overall beach volume change analysis) have been represented graphically in Figures 4.1 to 4.8 and in Table 4.1.

- During the month of October 2018 beach was found to have eroded at most of the stretches along 40 km except at Panathura where there was high accretion.
- During the month of November and December 2018, the sediment deposition has taken place almost throughout the entire stretch.
- During the month of January 2019 beach was found to have minor erosion and accretion almost all locations except high accretion noted at Kochuveli.
- There was a considerable amount of erosion has taken place during the month of February and March 2019.
- During the month of April 2019 beach considerable amount of deposition found at Beemapalli to Valiyathura beach. Beaches were found to have minor erosion at northern part of the port (Shangumugam to Valiyaveli) except very minor accretion at Kochuveli. Almost all locations at southern part of the port show erosion, other than Mullur, Adimalathura, Karumkulam, Neerody and Edapadu.
- In May 2019, most of the beaches in the northern side have high erosion and most of the beaches at southern side have accretion. Adimalathura beach have high accretion and Punthura beach got eroded.
- In June 2019, July 2019 and August 2019 offshore profiling was not carried out.
- September 2019 data has been considered for the overall beach volume change analysis

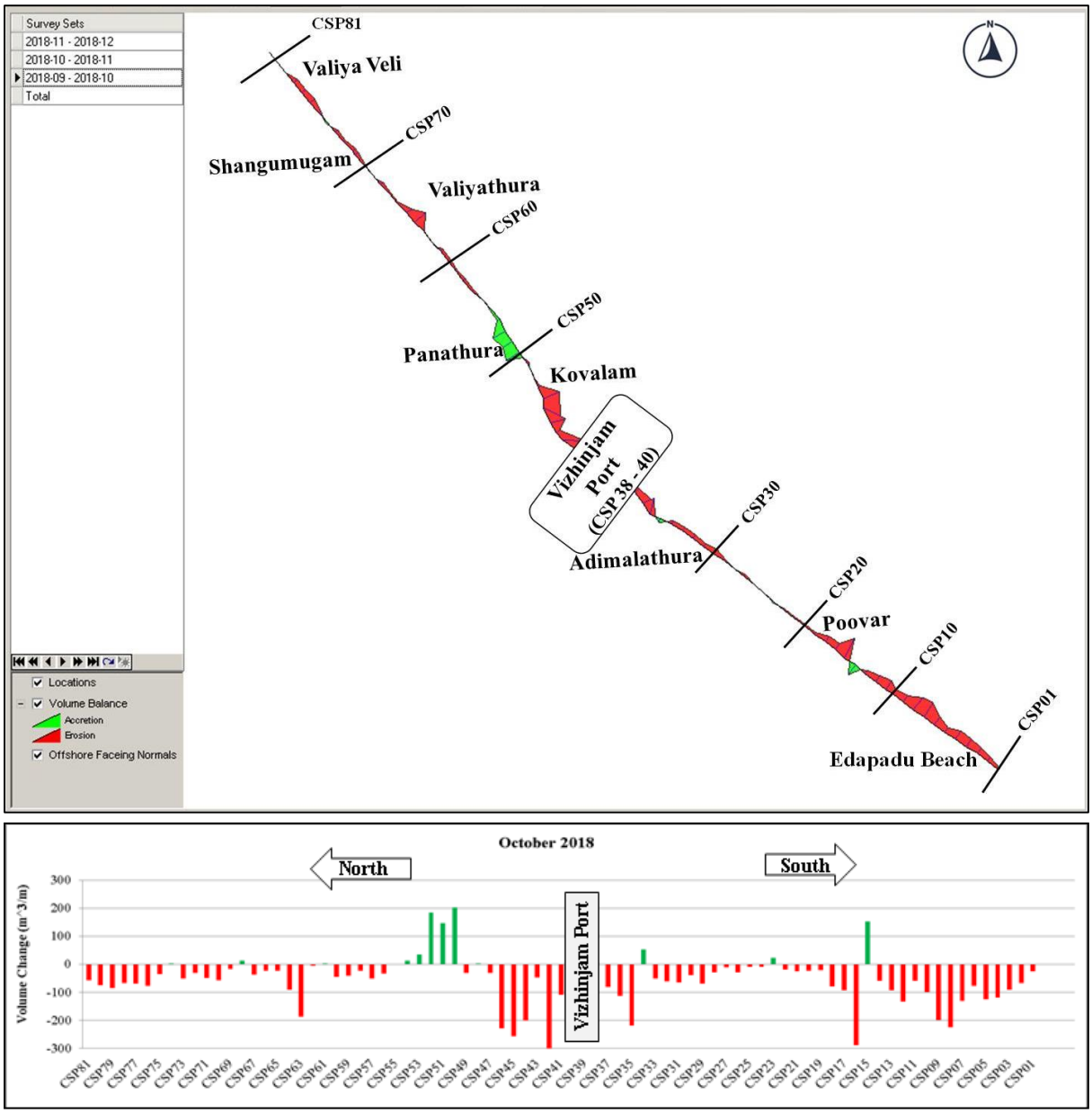


Figure 4.1 Monthly Beach Volume Changes in October 2018 in m^3/m

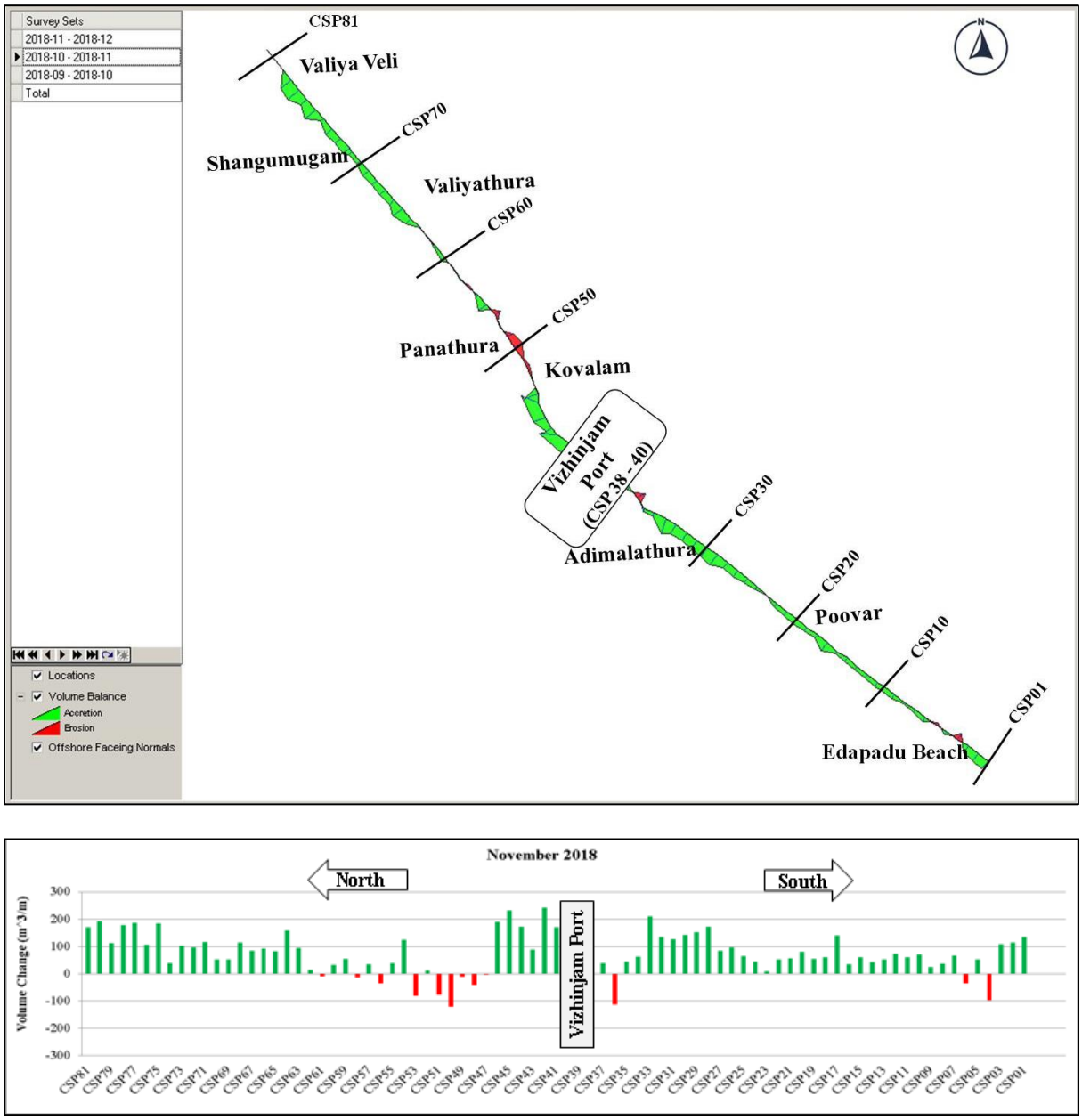


Figure 4.2 Monthly Beach Volume Changes in November 2018 in m^3/m

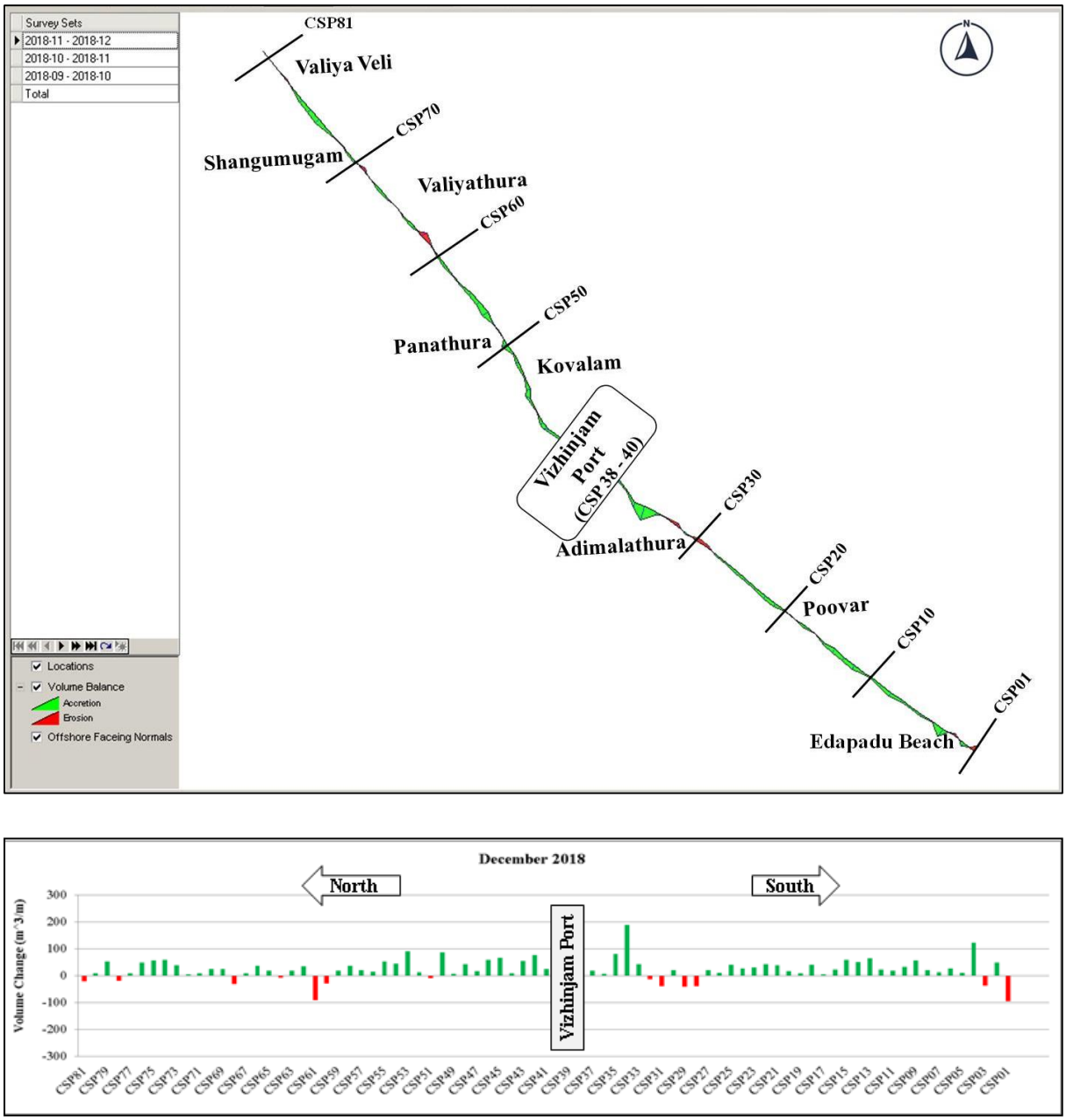
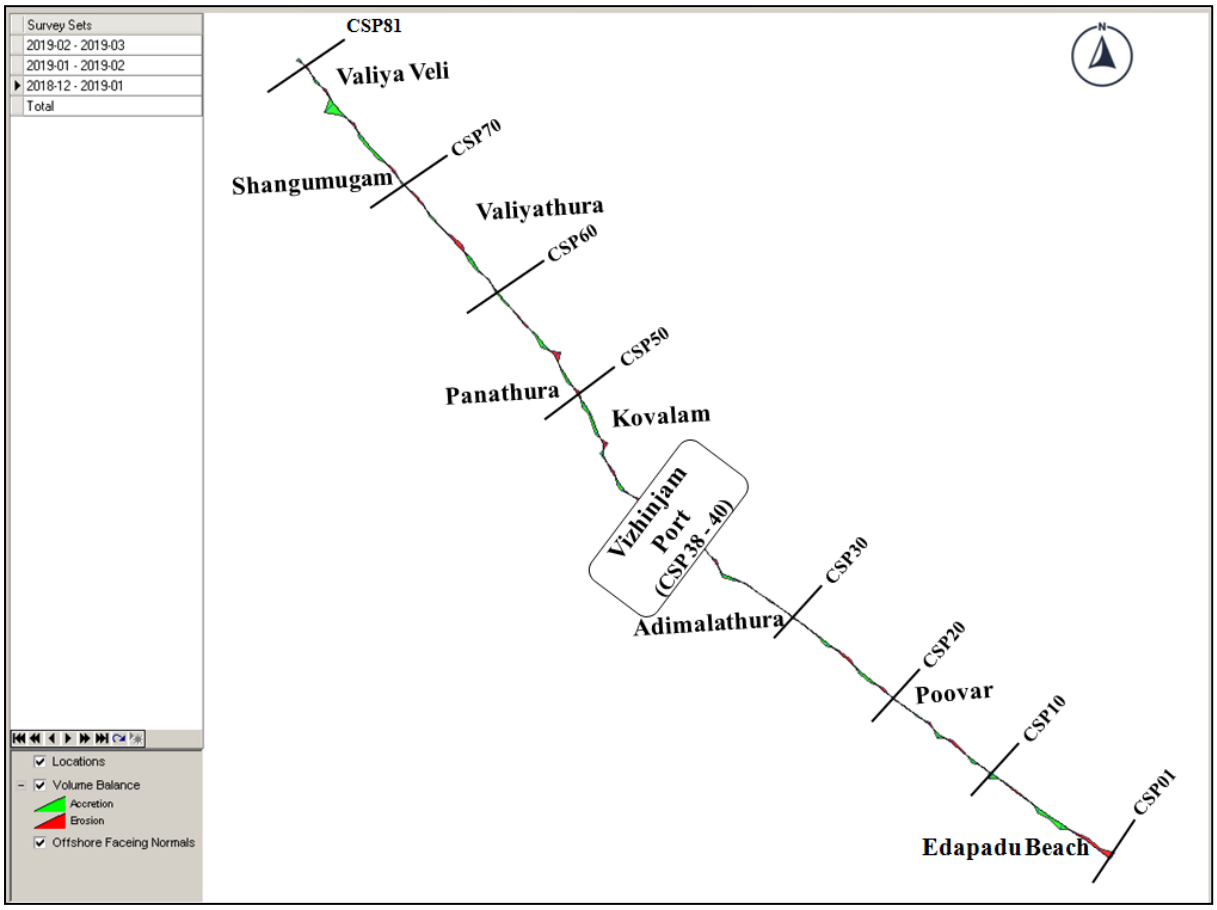


Figure 4.3 Monthly Beach Volume Changes in December 2018 in m^3/m



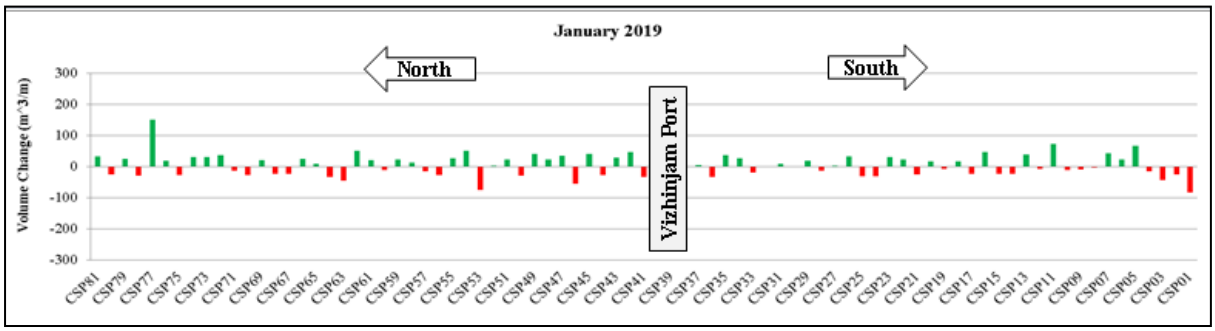


Figure 4.4 Monthly Beach Volume Changes in January 2019 in m^3/m

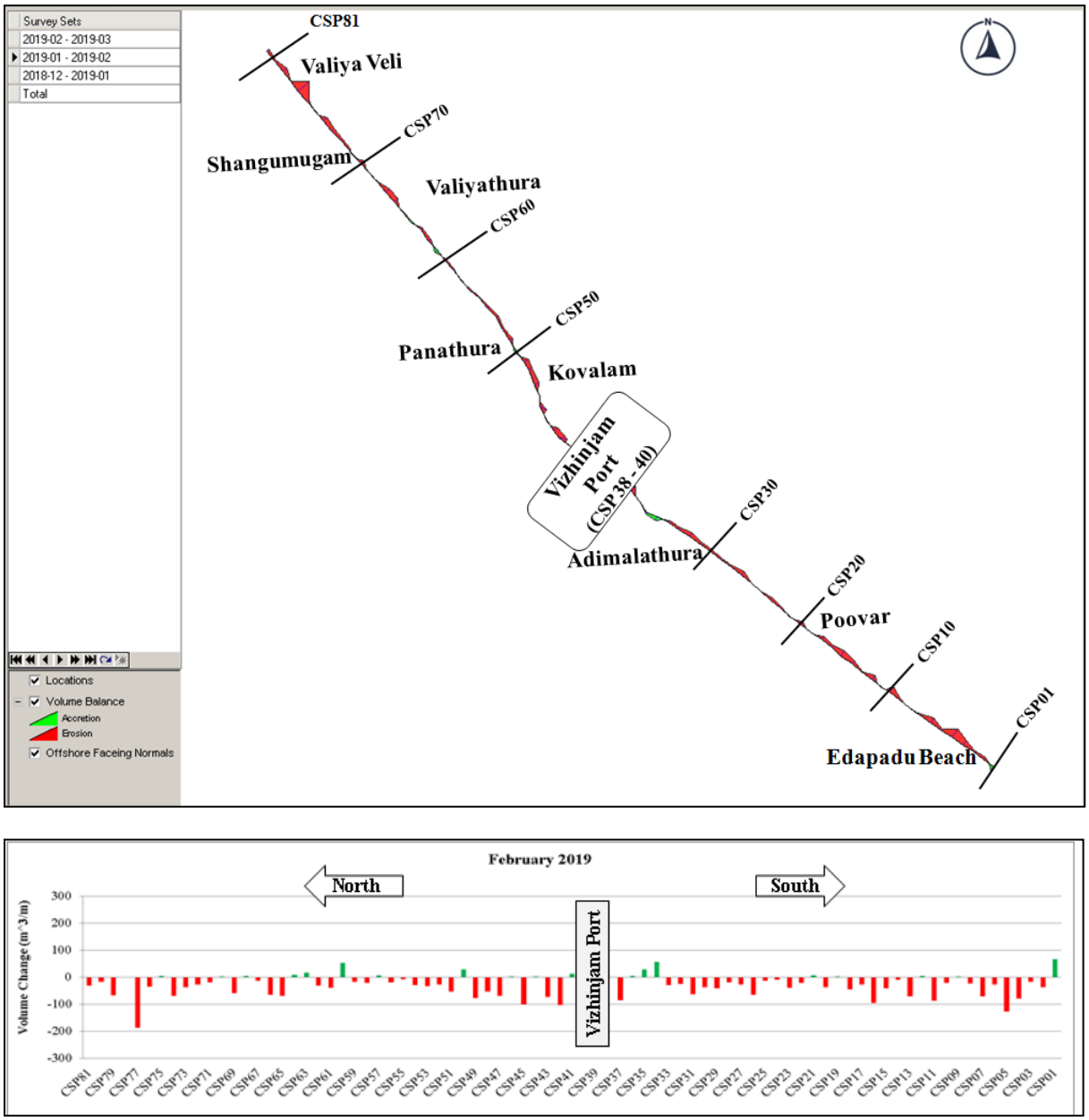


Figure 4.5 Monthly Beach Volume Changes in February 2019 in m^3/m

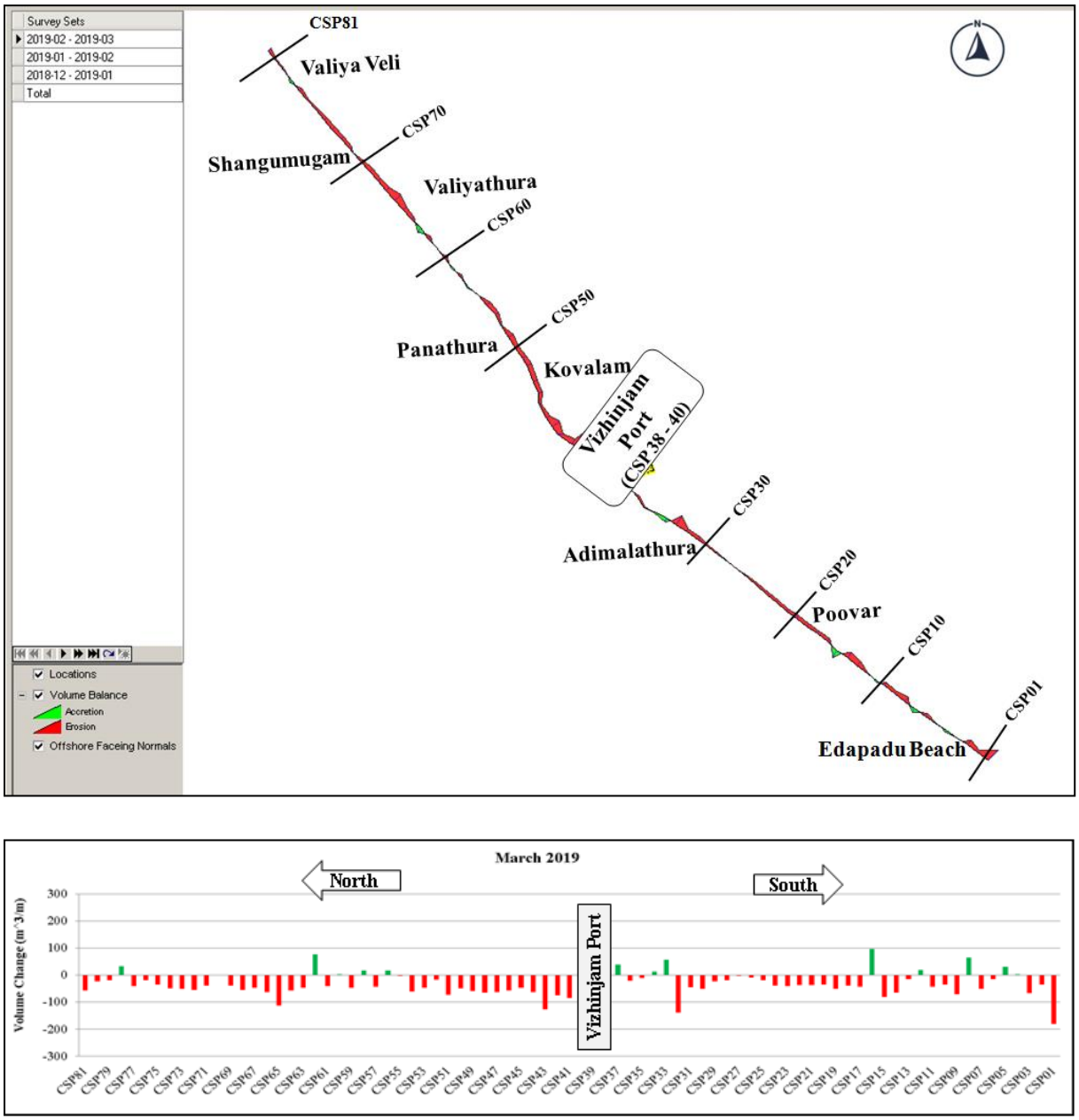


Figure 4.6 Monthly Beach Volume Changes in March 2019 in m^3/m

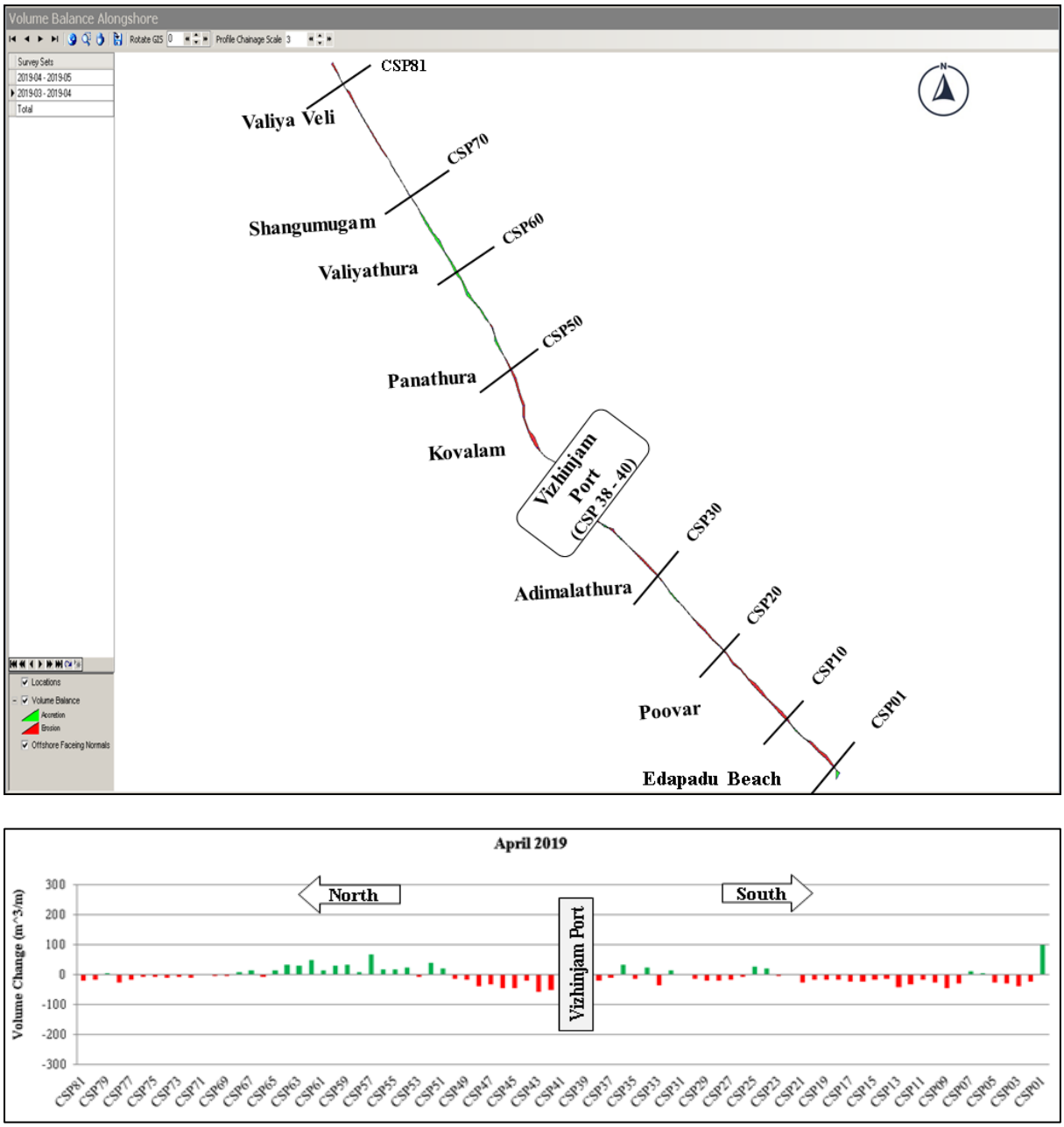
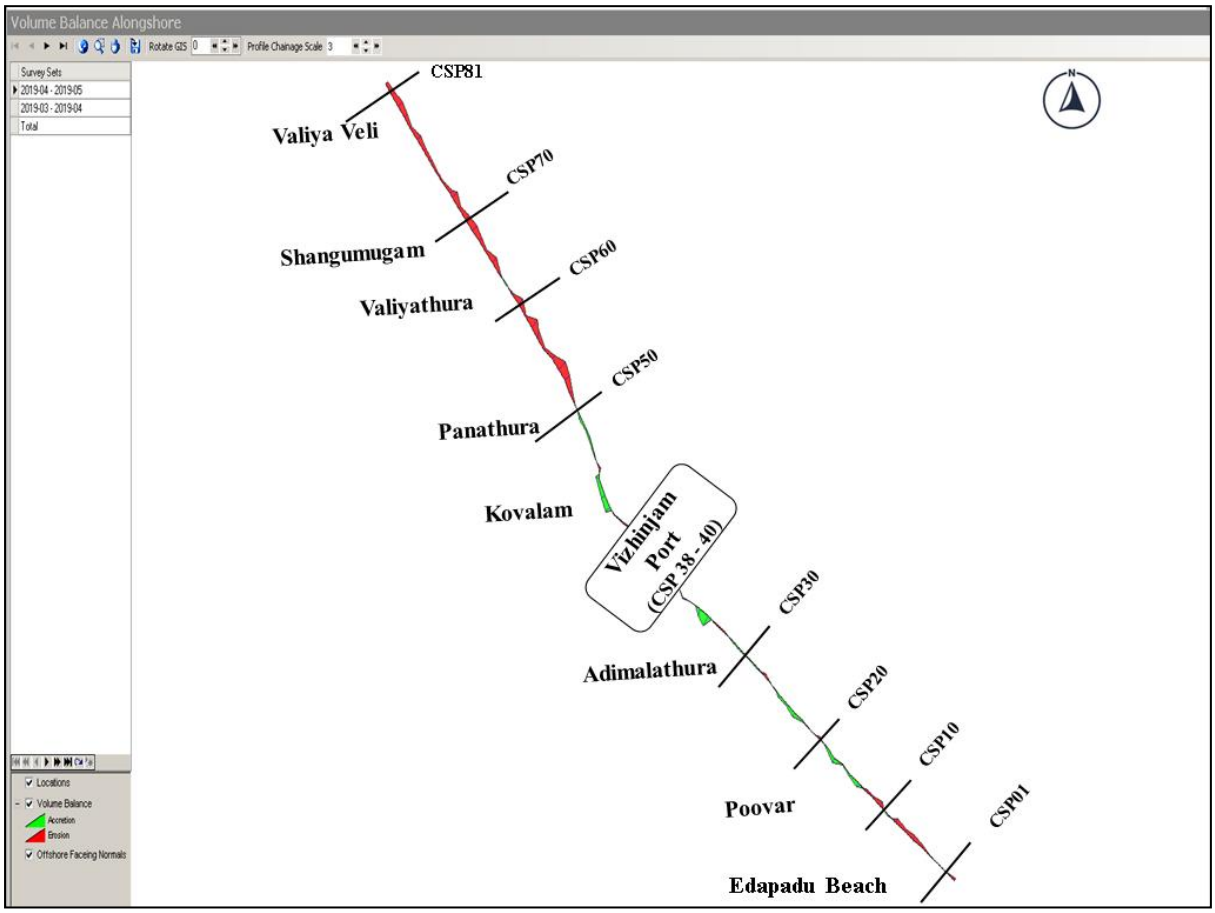


Figure 4.7 Monthly Beach Volume Changes in April 2019 in m^3/m



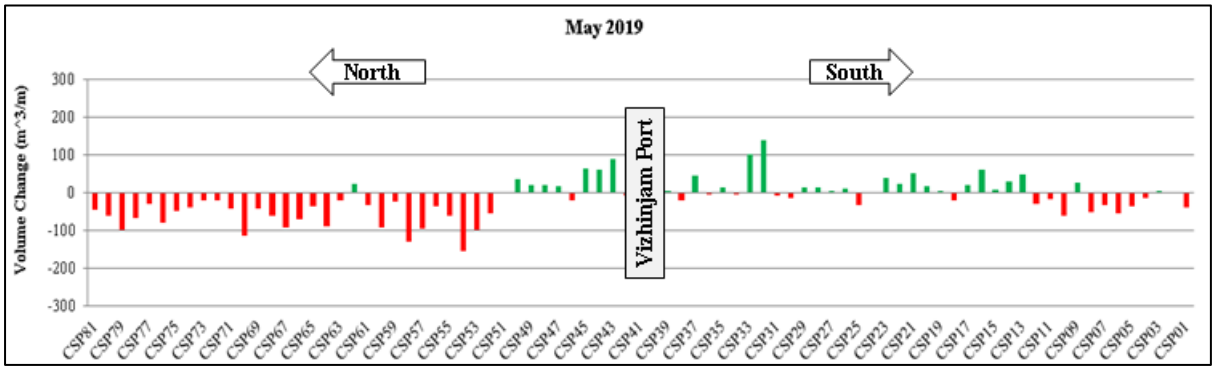


Figure 4.8 Monthly Beach Volume Changes in May 2019 in m^3/m

Table 4.1 Monthly Beach Volume Changes during the months from October 2018 to May 2019 in m^3/m

	October 2018	November 2018	December 2018	January 2019	February 2019	March 2019	April 2019	May 2019
CSP01	-25.07	134.51	-94.21	-82.44	65.98	-180.67	97.6	-38.16
CSP02	-67.68	114.14	48.19	-25.39	-37.65	-34.12	-22.74	-3.13
CSP03	-90.62	107.67	-36.56	-42.53	-17.87	-66.59	-39.31	1.99
CSP04	-118.51	-96.56	121.92	-15.44	-78.12	1.01	-30.2	-14.09
CSP05	-125.5	53.07	10.92	67.17	-125.92	30.58	-26.51	-35.48
CSP06	-76.17	-34.07	27.28	23.59	-26.66	-15.45	1.17	-53.75
CSP07	-130.79	66.09	12.9	43.76	-71.46	-51.11	10.7	-34.3
CSP08	-223.79	37.27	20.68	-3.87	-23.55	64.25	-29.43	-51.46
CSP09	-199.1	23.92	57.21	-8.95	1.3	-71.44	-47.23	24.96
CSP10	-98.59	71.02	33.76	-11.47	-21.69	-35.46	-26.54	-60.32
CSP11	-59.01	61.02	19.83	72.3	-86.75	-43.15	-16.81	-19.32
CSP12	-133.41	72.99	23.45	-6.55	5.69	18.68	-34.26	-30.32
CSP13	-93.64	53.43	65.19	38.57	-70.58	-15.78	-42.3	47.12
CSP14	-59.76	42.01	50.74	-22.75	-9.08	-65	-15.89	28.24
CSP15	153.54	61.03	58.41	-23.76	-40.49	-80.96	-17.16	7.29
CSP16	-289.29	33.88	22.87	46.73	-94.2	95.97	-25.04	59.91
CSP17	-92.81	141.42	4.82	-22.22	-27.38	-43.25	-24.44	19.18
CSP18	-78.21	59.96	40.36	16.29	-44.25	-39.71	-16.26	-21.1
CSP19	-20.97	54.28	8.36	-7.37	1.66	-49.98	-18.62	4.27
CSP20	-23.73	81.21	16.78	17.29	-36.73	-35.13	-17.56	15.82
CSP21	-24.2	57.36	38.07	-24.84	6.35	-36.6	-28	49.98
CSP22	-19.53	53.21	42.98	23.07	-20.86	-37.59	-3.63	21.39
CSP23	22.12	8.41	31.21	30.79	-39.42	-40.93	-4.35	38.83
CSP24	-8.49	45.11	27.53	-31.28	-9.16	-38.32	21.15	-2.63
CSP25	-9.14	65.4	39.97	-30.43	-13.61	-19.89	24.33	-33.42
CSP26	-29.9	95.94	11.24	32.44	-64.36	-9.8	-8.91	9.8
CSP27	-11.6	84.04	20.6	1.95	-26.65	-2.19	-16.53	2.14
CSP28	-28.14	173.05	-38.65	-12.45	-18.56	-18.2	-19.78	14.28
CSP29	-68.75	153.41	-41.65	19.41	-40.07	-23.14	-20.23	12.32
CSP30	-39.48	141.86	20.68	-1.69	-37.15	-50.33	-14.38	-14.96
CSP31	-64.5	127.19	-38.36	9.53	-63.2	-44.86	-3.15	-9.2
CSP32	-60.66	134.6	-13.68	-1.82	-24.18	-138.66	12.14	136.76
CSP33	-51.49	210.88	43.3	-19.28	-28.92	57.58	-36.93	101.76
CSP34	52.04	62.24	187.8	26.74	56.66	12.48	21.37	-6.78
CSP35	-218.68	45.14	80.29	36.12	28.86	-10.64	-13.98	12.9
CSP36	-112.04	-112.73	6.94	-32.39	4.05	-20.69	33.13	-5.76
CSP37	-80.84	39.26	19.11	3.92	-85.57	38.73	-13.04	44.97
CSP38	Port Area							
CSP39								
CSP40								
CSP41	-108.18	170.51	24.31	-33.11	12.74	-85.82	1.73	-21.81
CSP42	-300.42	241.59	77.27	46.07	-102.37	-75.78	-52.69	-7.33
CSP43	-47.00	89.11	54.29	28.67	-72.15	-126.27	-59.69	88.03
CSP44	-200.66	172.87	9.65	-28.01	3.38	-62.3	-19.55	58.7
CSP45	-256.04	232.7	66.54	40.33	-100.78	-46.54	-46.39	63.61
CSP46	-228.37	191.4	57.97	-55.11	0.5	-57.88	-46.03	-22.3
CSP47	-31.66	-3.94	16.13	34.36	-68.46	-62.89	-32.88	16.25
CSP48	1.43	-40.29	43.16	23.08	-52.77	-65.36	-38.81	19.44
CSP49	-31.96	-11.14	6.89	40.42	-75.94	-59.58	-17.61	20.63
CSP50	203.29	-120.19	85.9	-29.52	29.42	-48.13	-13.82	34.19
CSP51	145.76	-77.5	-8.21	23.21	-52.93	-73.58	21.15	-2.86
CSP52	183.57	12.19	12.97	3.5	-27.53	-17.38	37.09	-53.65
CSP53	34.36	-80.28	90.32	-74.27	-33.49	-47.93	-9.81	-98.8
CSP54	11.99	124.99	45.45	51.73	-28.51	-61.66	21.22	-153.93
CSP55	-0.57	39.72	52.57	26.99	-6.26	-2.23	16.19	-62.51
CSP56	-32.15	-34.7	15.87	-26.59	-19.07	17.71	16.63	-35.66
CSP57	-50.91	35.42	21.46	-15.58	6.45	-42.87	66.43	-96.51
CSP58	-22.24	-12.24	36.9	13.44	-20.42	17.08	6.81	-130.8
CSP59	-41.66	54.24	19.41	22.5	-16.19	-46.36	32.35	-25.47
CSP60	-44.11	32.18	-28.8	-10.26	53.35	1.87	29.2	-93.17
CSP61	0.56	-9.44	-90.71	21.43	-38.56	-40.95	13.86	-33.73
CSP62	-4.68	15.54	33.95	51.05	-31.42	75.98	46.98	23.79
CSP63	-187.3	94.9	18.86	-44.52	17.11	-46.7	29.91	-21.92
CSP64	-90.97	157.7	-7.71	-32.02	9.61	-56.48	30.78	-90.08
CSP65	-22.56	82.09	18.65	8.77	-67.94	-112.14	12.8	-36.89
CSP66	-23.69	93.53	36.36	24.74	-63.99	-63.35	-7.35	-70.83

CSP67	-36.56	85.31	9.09	-22.4	-14	-46.16	13.07	-91.48
CSP68	12.39	114.84	-30.94	-22.34	5.7	-55.35	6.43	-62.05
CSP69	-17.15	53.33	24.65	21.76	-58.42	-38.18	-6.07	-43.48
CSP70	-56.74	51.81	25.3	-26.26	3.33	-0.48	-5	-115
CSP71	-49.22	116.93	9.16	-12.25	-19.56	-39.21	-3.11	-43.02
CSP72	-31.16	96.71	5.22	37.78	-26.41	-54.74	-10.42	-20.96
CSP73	-51.25	103.64	39.11	30.84	-36.28	-50.18	-9.61	-22.29
CSP74	2.51	38.05	59.44	31.79	-69.9	-48.97	-10.53	-39.14
CSP75	-35.23	185.07	55.82	-26.71	5.7	-35.5	-8.09	-50.41
CSP76	-76.68	107.38	49.62	18.79	-35.18	-19.2	-8.99	-80.17
CSP77	-68.02	186.3	8.29	149.72	-186.24	-40.17	-17.42	-31.12
CSP78	-66.15	178.26	-18.45	-28.85	-0.28	32.03	-26.27	-68.11
CSP79	-84.48	113.17	52.14	24.62	-67.84	-19.52	0.75	-97.36
CSP80	-75.61	193.22	9.56	-25.24	-17.42	-23.89	-17.42	-62.04
CSP81	-56.28	170	-21.71	31.97	-31.9	-56.79	-22.13	-44.63

4.1.2 Seasonal Beach Volume variations from October 2018 to May 2019

Seasonal variation has been analyzed as post monsoon (October 2018 to November 2018), fair weather period (December 2018 to March 2019) and pre-monsoon period (April 2019 to May 2019) for the period October 2018 to September 2019. The results have been presented to depict the total changes that occur in a particular season by analyzing profiles between each month in a season. However, the beach profile analysis for the monsoon period (June 2019 to September 2019) has not been carried out due to the rough sea condition.

4.1.2.1 *Results for Beach Volume Change in Post Monsoon 2018 (October 2018 - November 2018)*

Beach volume change during post monsoon shows accretion trend at most of the locations on the 40km stretch beach. The entire stretch records a deposition except there is predominant erosion at Panathura to Punthura and for a small patch at Vallavilay and Mullur during this period as shown in Figure 4.9.

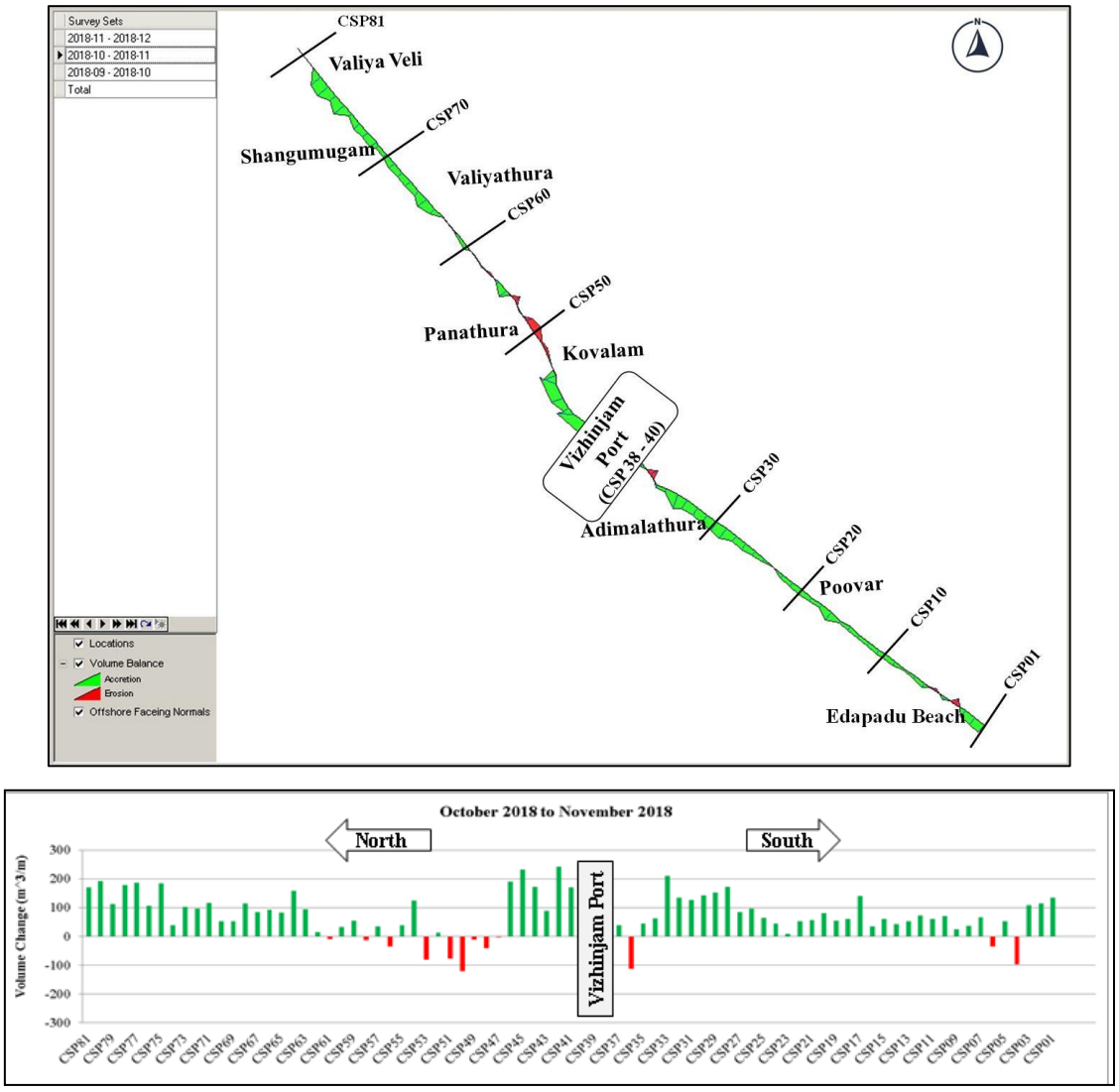


Figure 4.9 Seasonal Beach Volume Changes during Post Monsoon in m^3/m

4.1.2.2 *Results for Beach Volume Change in Fair Weather Period 2019 (December 2018-March 2019)*

During the fair weather period (Figure 4.10) the beach exhibits erosion for most of the locations compared to post monsoon season. Small accretions are noticed at Neerody, Poovar, Mullur, Punthura and Beemapally. The beach on the northern part of the Port, between Kovalam to Panathura and Punthura shows erosion trend for both post monsoon and fair weather periods.

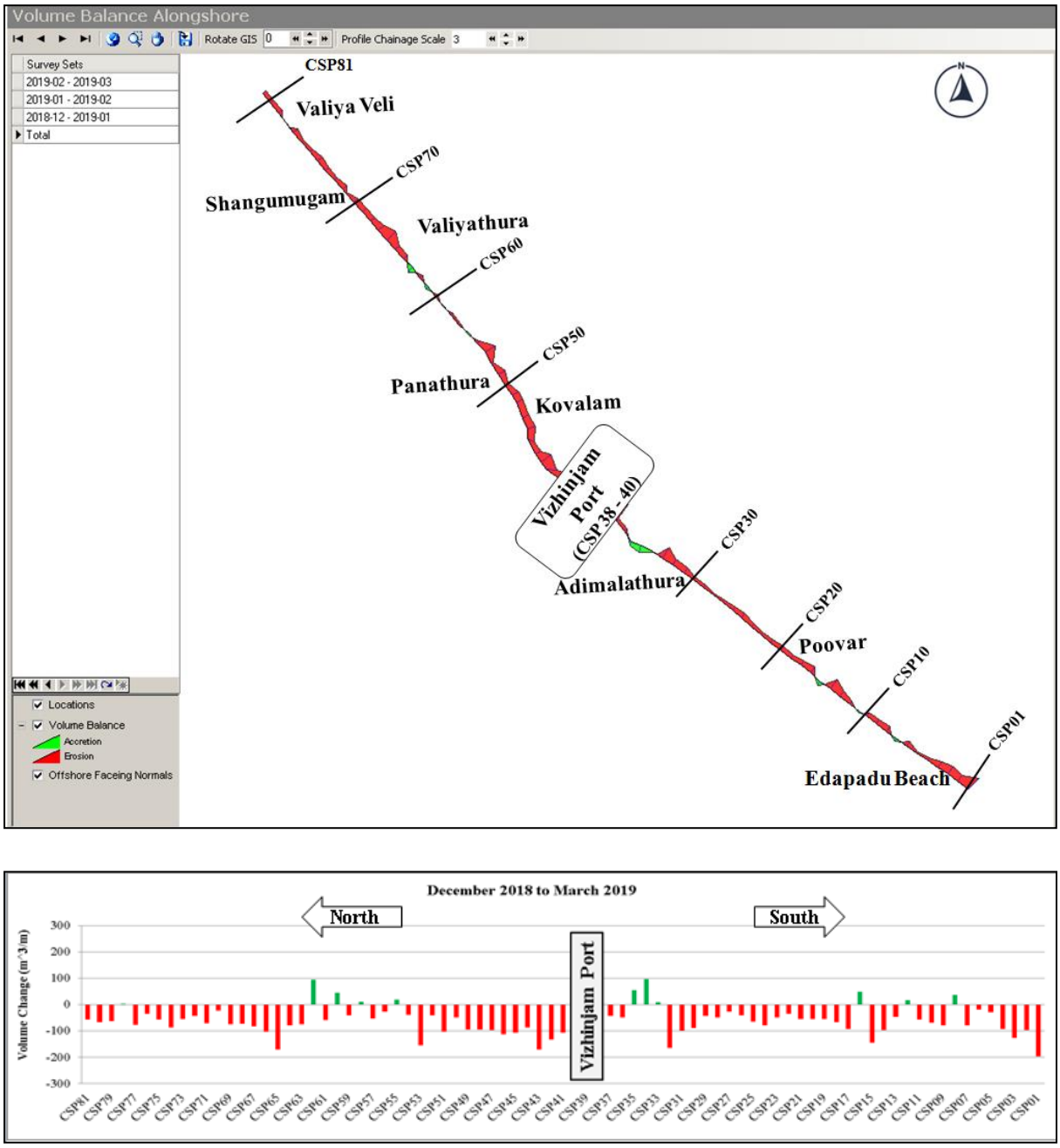


Figure 4.10 Seasonal Beach Volume Changes during Fair weather period in m^3/m

4.1.2.3 *Results for Beach Volume Change in Pre-Monsoon Period 2019 (April 2019-May 2019)*

Most of the locations underwent net erosion for the period of April 2019 to May 2019 (Figure 4.11). Significant erosion noticed at northern side of the port, Valiyathura to Thumba. Kovalam, Panathura and Cheriyathura beaches show accretion. During the same period, at south of the port, Adimalthura to Mullur region shows considerable amount of deposition.

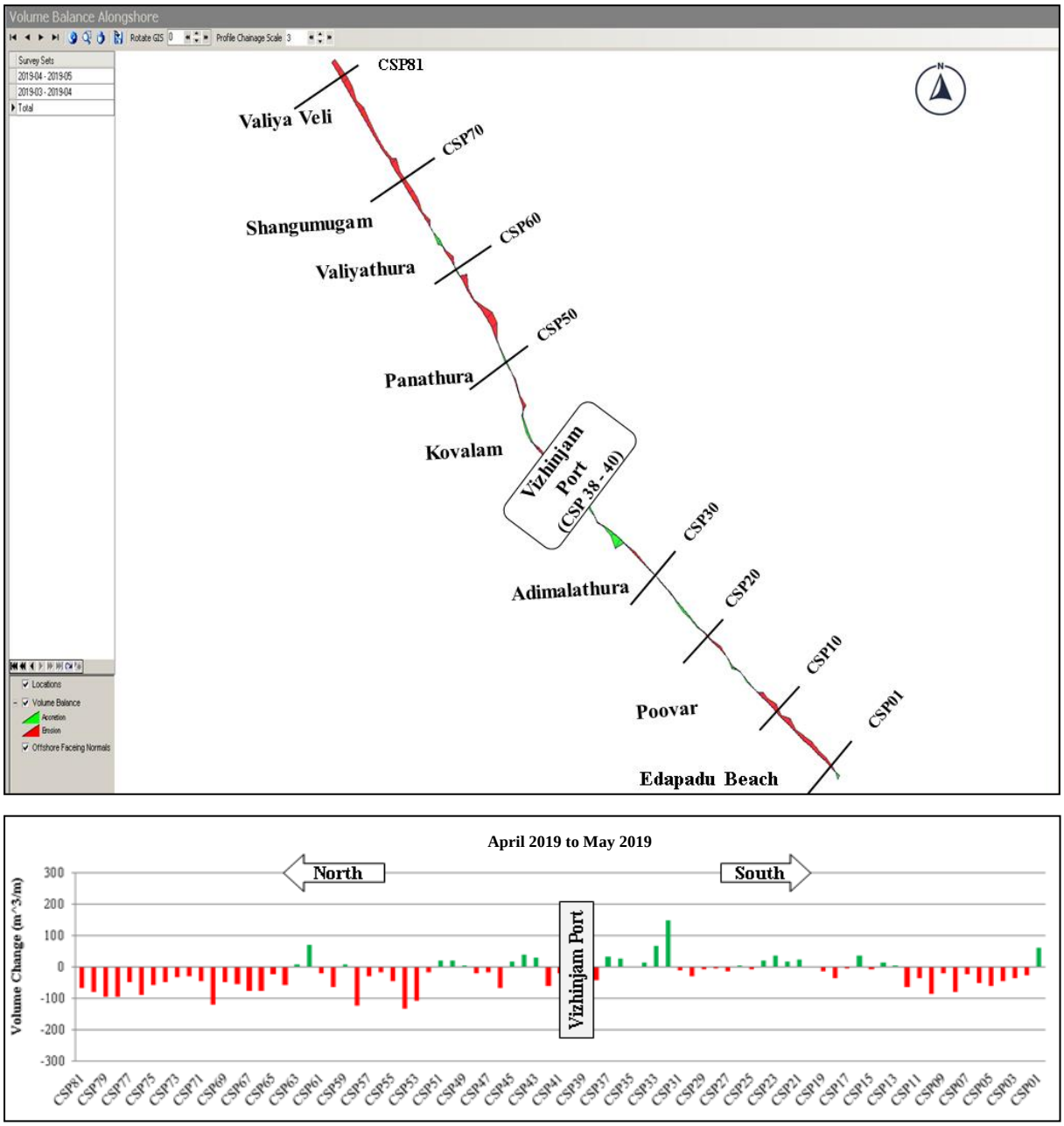


Figure 4.11 Seasonal Beach Volume Changes during Pre-Monsoon Period 2019 in m^3/m

4.1.3 Overall beach volume variation during October 2018 to September 2019

The overall beach volume change shows erosion on almost all locations except at CSP 22-23 (Karumkulam), CSP 32-33 (Adimalathura), CSP 35-38 (Mullur), CSP 61 (Cheriyathura). Accretion rate is high at CSP-33 (Adimalathura) and erosion rate is high at CSP-16 (Poovar) due to river mouth opening and estuary. During monsoons with heavy rainfall, the beach sands are washed away. The beach profile data was not collected at transects

CSP 49-CSP 52 (Panathura) during September 2019 due to rough sea condition the location was not approachable. So, these transects are not considered for the analysis.

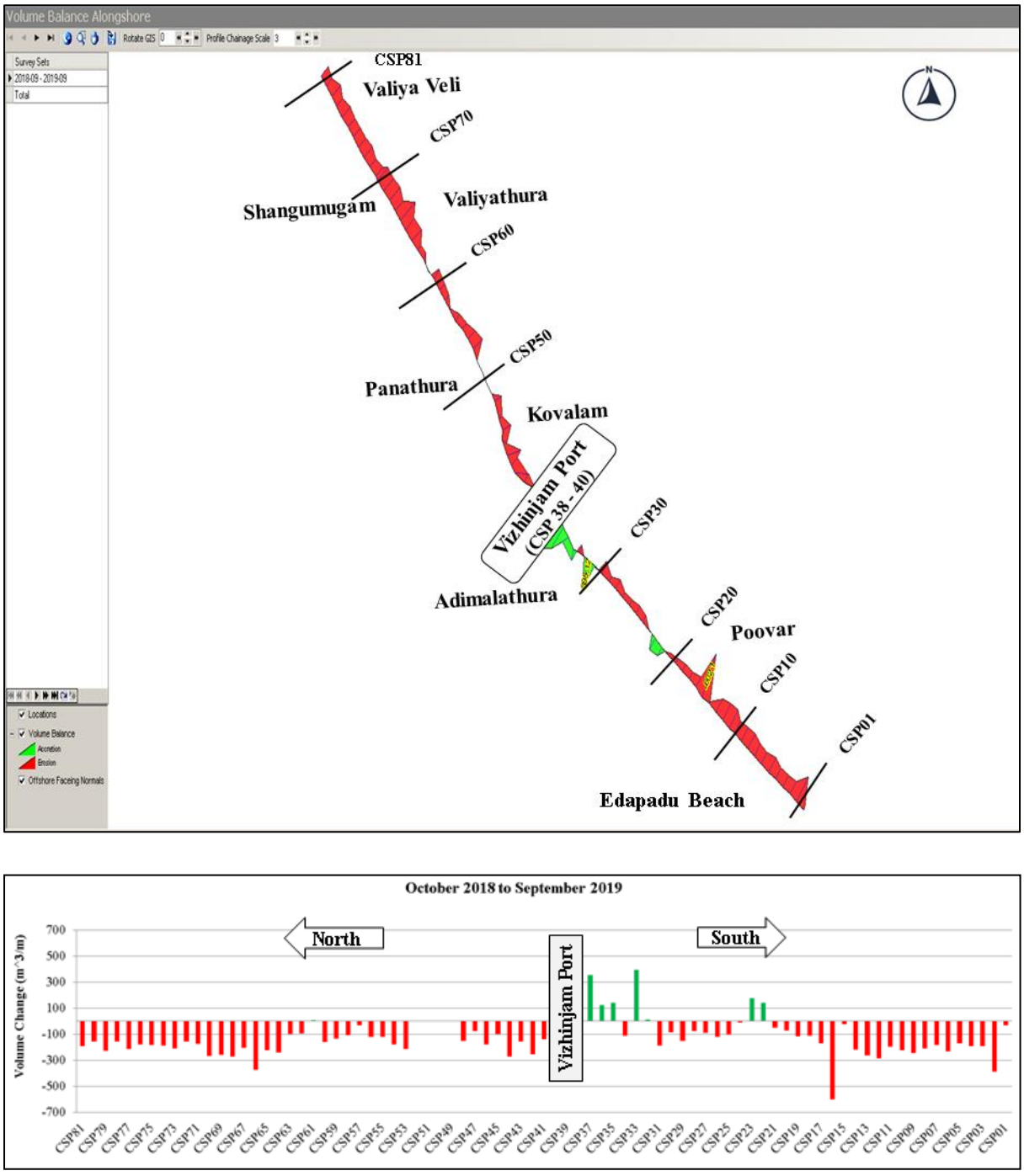


Figure 4.12 Overall Beach Volume Changes - October 2018 to September 2019 in m^3/m

Table 4.2 Seasonal and Overall Beach Volume Changes in m^3/m

Location	Post Monsoon 2018 (October 2018 to November 2018)	Fair weather 2018-2019 (December 2018 to March 2019)	Pre-Monsoon 2019 (April 2019 to May 2019)	Overall (October 2018 to September 2019)
CSP01	134.51	-197.13	59.44	-33.08
CSP02	114.14	-97.16	-25.87	-388.56
CSP03	107.67	-126.99	-37.32	-193.86
CSP04	-96.56	-92.55	-44.29	-192.25
CSP05	53.07	-28.17	-61.99	-169.62
CSP06	-34.07	-18.52	-52.58	-231.58
CSP07	66.09	-78.81	-23.6	-183.51
CSP08	37.27	36.83	-80.89	-209.76
CSP09	23.92	-79.09	-22.27	-243.67
CSP10	71.02	-68.62	-86.86	-220.91
CSP11	61.02	-57.6	-36.13	-196.08
CSP12	72.99	17.82	-64.58	-285.5
CSP13	53.43	-47.79	4.82	-264.71
CSP14	42.01	-96.83	12.35	-218
CSP15	61.03	-145.21	-9.87	-21.92
CSP16	33.88	48.5	34.87	-602.1
CSP17	141.42	-92.85	-5.26	-167.88
CSP18	59.96	-67.67	-37.36	-110.25
CSP19	54.28	-55.69	-14.35	-115.46
CSP20	81.21	-54.57	-1.74	-72.28
CSP21	57.36	-55.09	21.98	-50.93
CSP22	53.21	-35.38	17.76	141.13
CSP23	8.41	-49.56	34.48	174.64
CSP24	45.11	-78.76	18.52	-9.66
CSP25	65.4	-63.93	-9.09	-103.32
CSP26	95.94	-41.72	0.89	-119.74
CSP27	84.04	-26.89	-14.39	-91.88
CSP28	173.05	-49.21	-5.5	-78.35
CSP29	153.41	-43.8	-7.91	-152.32
CSP30	141.86	-89.17	-29.34	-86.22
CSP31	127.19	-98.53	-12.35	-186.67
CSP32	134.6	-164.66	148.9	11.53
CSP33	210.88	9.38	64.83	395.13
CSP34	62.24	95.88	14.59	-111.45
CSP35	45.14	54.34	-1.08	143.14
CSP36	-112.73	-49.03	27.37	123.56
CSP37	39.26	-42.92	31.93	352.38
CSP38	**Port Area**			
CSP39				
CSP40				
CSP41	170.51	-106.19	-20.08	-140.22
CSP42	241.59	-132.08	-60.02	-255.13
CSP43	89.11	-169.75	28.34	-155.85
CSP44	172.87	-86.93	39.15	-273.37
CSP45	232.7	-106.99	17.22	-98.72
CSP46	191.4	-112.49	-68.33	-176.59
CSP47	-3.94	-96.99	-16.63	-76.19
CSP48	-40.29	-95.05	-19.37	-149.71
CSP49	-11.14	-95.1	3.02	No data
CSP50	-120.19	-48.23	20.37	No data
CSP51	-77.5	-103.3	18.29	No data
CSP52	12.19	-41.41	-16.56	No data
CSP53	-80.28	-155.69	-108.61	-214.7
CSP54	124.99	-38.44	-132.71	-179.26
CSP55	39.72	18.5	-46.32	-120.75
CSP56	-34.7	-27.95	-19.03	-119.77
CSP57	35.42	-52	-30.08	-33.48
CSP58	-12.24	10.1	-123.99	-108.33
CSP59	54.24	-40.05	6.88	-134.47

CSP60	32.18	44.96	-63.97	-160.43
CSP61	-9.44	-58.08	-19.87	9.25
CSP62	15.54	95.61	70.77	-92.42
CSP63	94.9	-74.11	7.99	-97.21
CSP64	157.7	-78.89	-59.3	-239.69
CSP65	82.09	-171.31	-24.09	-223.53
CSP66	93.53	-102.6	-78.18	-374.52
CSP67	85.31	-82.56	-78.41	-204.06
CSP68	114.84	-71.99	-55.62	-270.85
CSP69	53.33	-74.84	-49.55	-258.75
CSP70	51.81	-23.41	-120	-268.13
CSP71	116.93	-71.02	-46.13	-174.96
CSP72	96.71	-43.37	-31.38	-157.45
CSP73	103.64	-55.62	-31.9	-209.35
CSP74	38.05	-87.08	-49.67	-189.52
CSP75	185.07	-56.51	-58.5	-181.05
CSP76	107.38	-35.59	-89.16	-177.43
CSP77	186.3	-76.69	-48.54	-212.64
CSP78	178.26	2.9	-94.38	-154.83
CSP79	113.17	-62.74	-96.61	-229.35
CSP80	193.22	-66.55	-79.46	-154.26
CSP81	170	-56.72	-66.76	-190.97

4.1.4 Seasonal Beach volume variation between 2017-2018 and 2018-2019

Beach Volume Changes - October 2017 and October 2018 (Post Monsoon Period)

The beach volume changes for October 2017 and October 2018 (Figure 4.13) shows accretion at Vettucaud to Kochuveli, Pannathura and erosion at Valliyathura to Punthura, Kovalam, and Mullur to Adimalathura.

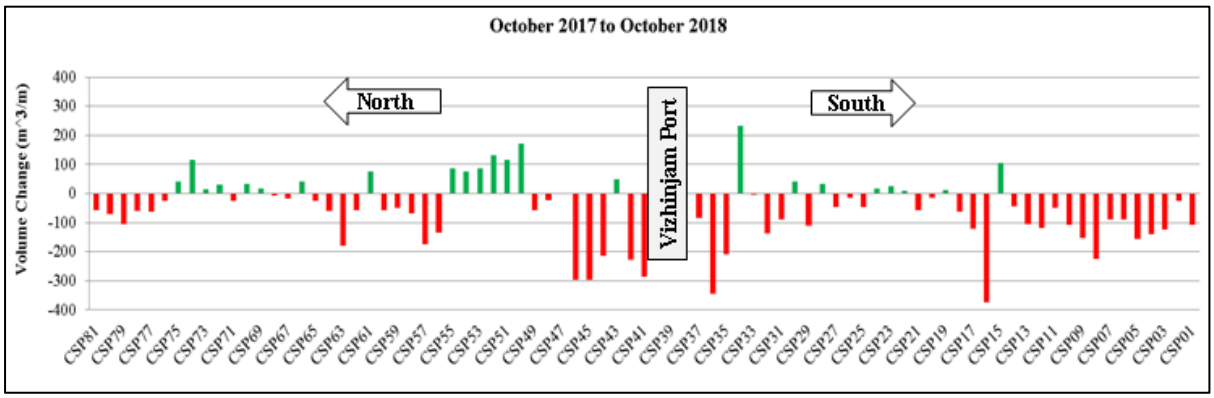


Figure 4.13 Beach Volume Changes - October 2017 and October 2018 in m^3/m

Beach Volume Changes - February 2018 and February 2019 (Fair weather period)

The beach volume changes for February 2018 and February 2019 (Figure 4.14) shows accretion at Kochuveli, Punthura, Adimalathura, Edapadu and erosion at Vettucaud, Valliyathura, Pullavila to Neerody.

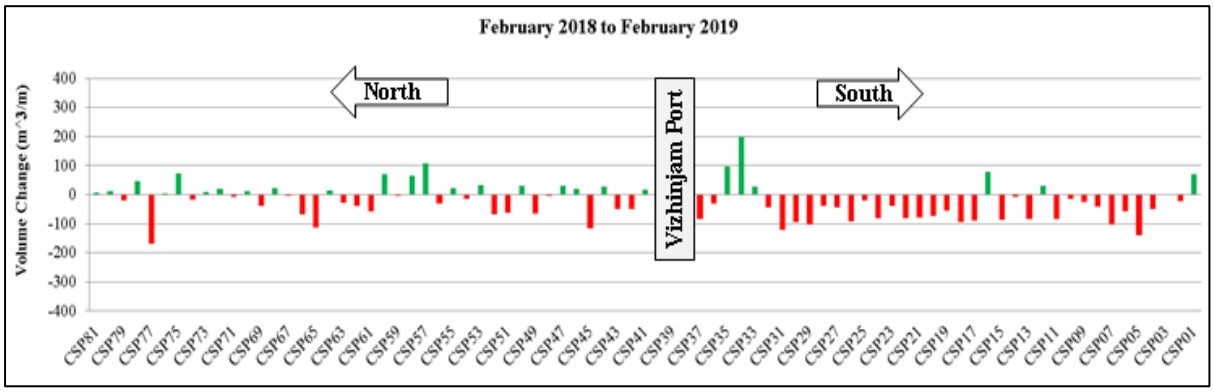


Figure 4.14 Beach Volume Changes - February 2018 and February 2019 in m^3/m

Beach Volume Changes - April 2018 and April 2019 (Pre-Monsoon Period)

The beach volume changes for April 2018 and April 2019 (Figure 4.15) shows accretion at Valliyathura to Beemapally, Poovar, Edapadu beach and erosion at Vettucaud, Pannathura, Karumkulam, Neerody to Paruthiyoor.

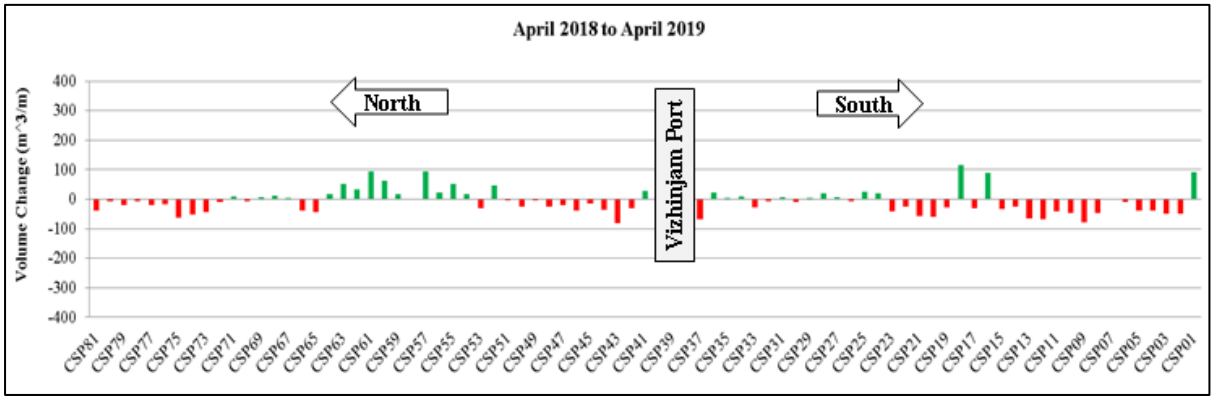


Figure 4.15 Beach Volume Changes - April 2018 and April 2019 in m^3/m

Beach Volume Changes – September 2018 and September 2019 (Monsoon Period)

The beach volume changes for September 2018 and September 2019 (Figure 4.16) shows accretion at Mullur to Adimalathura, Karumkulam and remaining all other regions exhibits erosion. This indicates erosion during September 2019 along the coast when compared to September 2018.

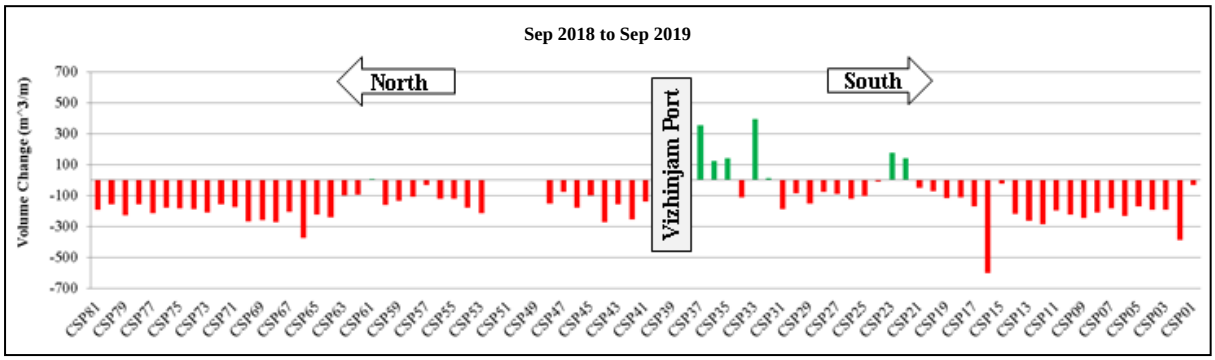


Figure 4.16 Beach Volume Changes - September 2018 and September 2019 in m^3/m

4.1.5 Overall Beach volume variation during February 2015 and February 2019

The beach volume changes for February 2015 and February 2019 (Figure 4.17) shows accretion at Valliyaveli to Vettucaud, Mullur to Adimalathura and Poovar and erosion at Shangumugham to Beemapally, Punthura, Pannathura, Kovalam, Poovar to Edapadu beach.

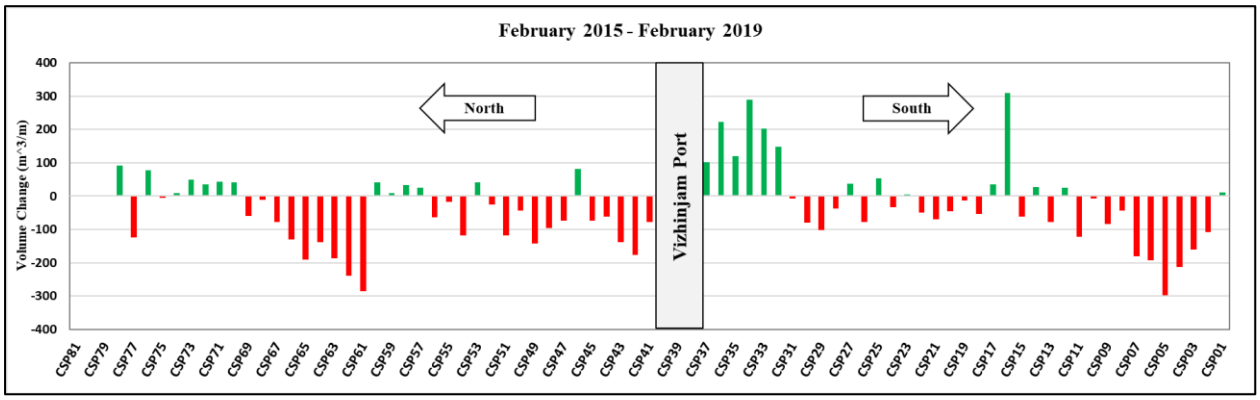


Figure 4.17 Beach Volume Changes - February 2015 and February 2019 in m^3/m

4.2 Results for Shoreline Change Analysis from Satellite images

In the previous submitted Annual report for the period October 2017 to September 2018, the result from the shoreline change analysis using high resolution satellite images carried out for 2000-2018 and annual variation for the year 2015-2016, 2016-2017, 2017-2018 has been presented. As a part of NGT direction, the shoreline change analysis has been carried out for the year 2000-2010, 2010-2018, 2000-2018 using high resolution LISS 4 (5m) and PAN (2.5m) images to study the changes before and after 2010. Further, the shoreline change analysis has been carried out for the years 2000-2005, 2005-2010, 2010-2015, 2015-2018 to study the immediate changes prior and after port commencement activity (December 2015).

The spots of erosion listed from the above analysis using high resolution satellite images are Valliyathura (CSP63 to CSP67), Punthura (CSP53 to CSP57), Neerody to Edapadu (CSP01 to CSP09). Hence, in continuation with the earlier Annual report October 2017- September 2018, this annual report compiles the monthly, seasonal and overall shoreline change over the period from October 2018 to September 2019 using available high resolution satellite images.

4.2.1 Monthly Shoreline Change Analysis from October 2018 to September 2019

The monthly shoreline change analysis from October 2018 to September 2019 carried out using available high resolution satellite images has been presented in the Figure 4.18 to 4.29 respectively.

- In October 2018 (Figure 4.18), the accretion is noted at Shangumugham, Beemapally, Punthura, Kovalam, Karumkulam and Edpadu beach while erosion is noted at Vetucaud, Valliyathura, Mullur, Adimalathura, Pullavila, Poovar, Neerody and Vallavilay.
- The shoreline change analysis map of November 2018 (Figure 4.19) shows accretion along most of the coastal stretch except erosion is noted from Valliyathura to Beemapally, Punthura creek to Panathura and Edapadu beach.
- The shoreline change analysis map of December 2018 (Figure 4.20) shows accretion along the coast except erosion is noted at few transects of Valliyathura, Panathura, Poovar, Paruthiyoor, Neerody, Vallavilay and Edapadu beach.
- The accretion is noted at Thumba, Pannathura, Kovalam, Mullur to Karumkulam, Paruthiyoor to Neerody while the erosion is noted from Kochuveli to Valliyathura, Punthura and few transects near Panathura, Poovar, Vallavilay and Edapadu beach for the month of January 2019 (Figure 4.21).
- The shoreline change analysis map of February 2019 (Figure 4.22) shows that the erosion is noted along most of the coast except spots of accretion at Kochuveli, Vettucaud, Valliyathura, Punthura and Kovalam.
- The shoreline change analysis map of March 2019 (Figure 4.23) shows that the erosion is noted along most of the coast except accretion at Shangumugam, south of Pannathura, Paruthiyoor and Neerody.
- The accretion is noted at few transects of Kochuveli, Neerody and Vallavilay while erosion is noted from Vettucaud, Kovalam, southern transects of Poovar, Paruthiyoor for the month of April 2019 (Figure 4.24).

- The shoreline change analysis map of May 2019 (Figure 4.25) shows that the erosion is noted along most of the coast except spots of accretion at few transects at Valliyathura, Pannathura, Mullur, Kovalam, Adimalathura, south of Karumkulam and Vallavilay.
- The shoreline change analysis map of June 2019 (Figure 4.26) shows that the erosion is noted along most of the coast except accretion at Pannathura, Mullur, Adimalathura, Poovar and Neerody.
- The monthly shoreline change analysis (July 2019) carried out using Sentinel (10m) and Resourcesat (5m) has been presented in Figure 4.27. The erosion is noted at Kochuvelli, Punthura, northern transects of Panathura, Karumkulam, Poovar and Paruthiyoor for July 2019.
- The shoreline change analysis map of August 2019 (Figure 4.28) shows accretion at few transects at Cheriyathura, Panathura, Mullur, Kovalam and north of Edappadu beach while erosion is noticed along most of the coast .
- The shoreline change analysis map of September 2019 (Figure 4.29) shows that the accretion is noticed along most of the coast except erosion at Valliyathura, Cheriyathura, southern transects of Pannathura, Mullur, Neerody and Vallavilay.

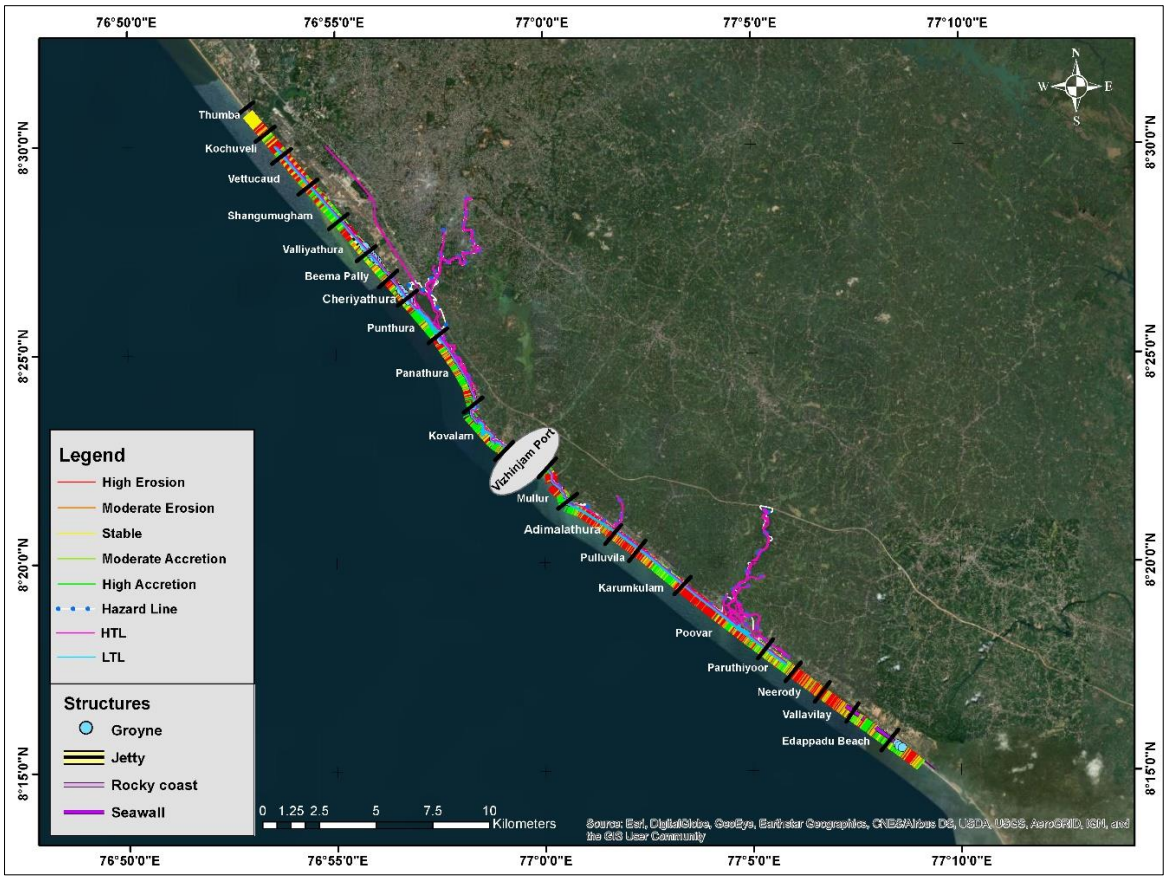


Figure 4.18 Shoreline Change Map - October 2018

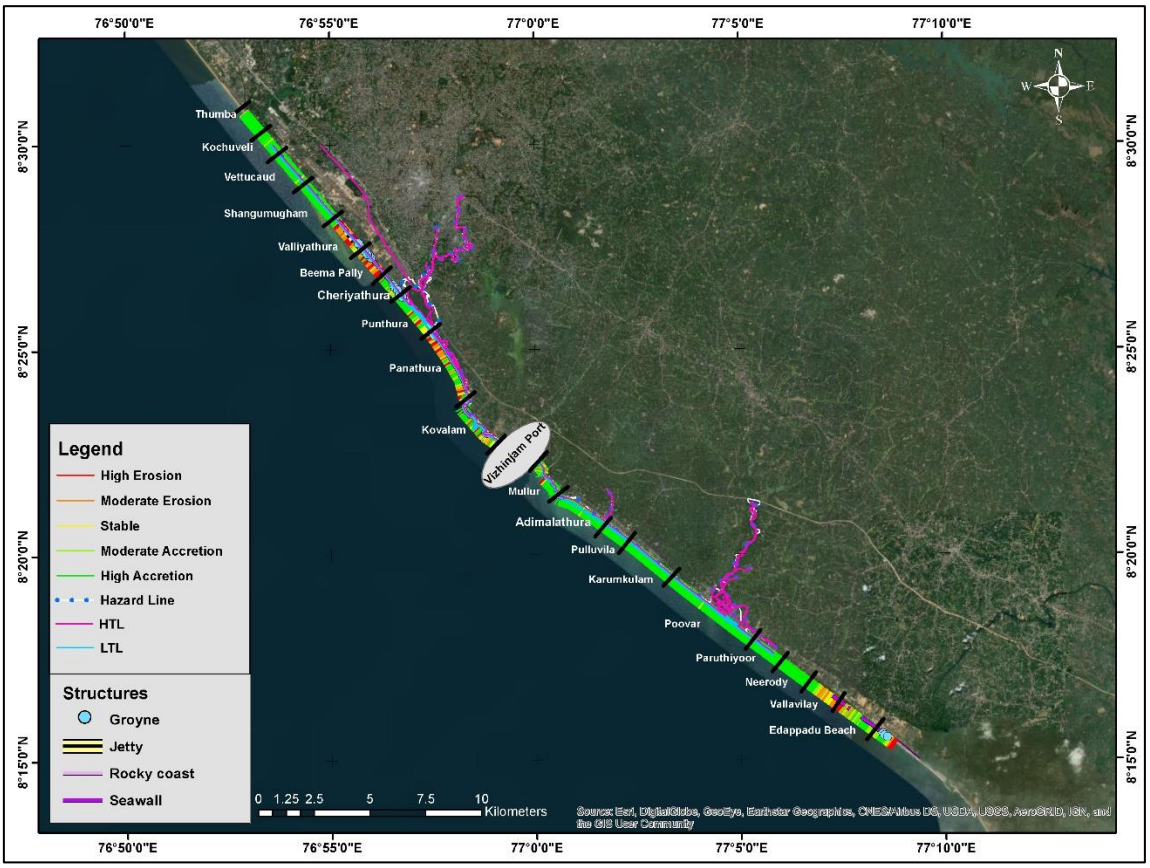


Figure 4.19 Shoreline Change Map - November 2018

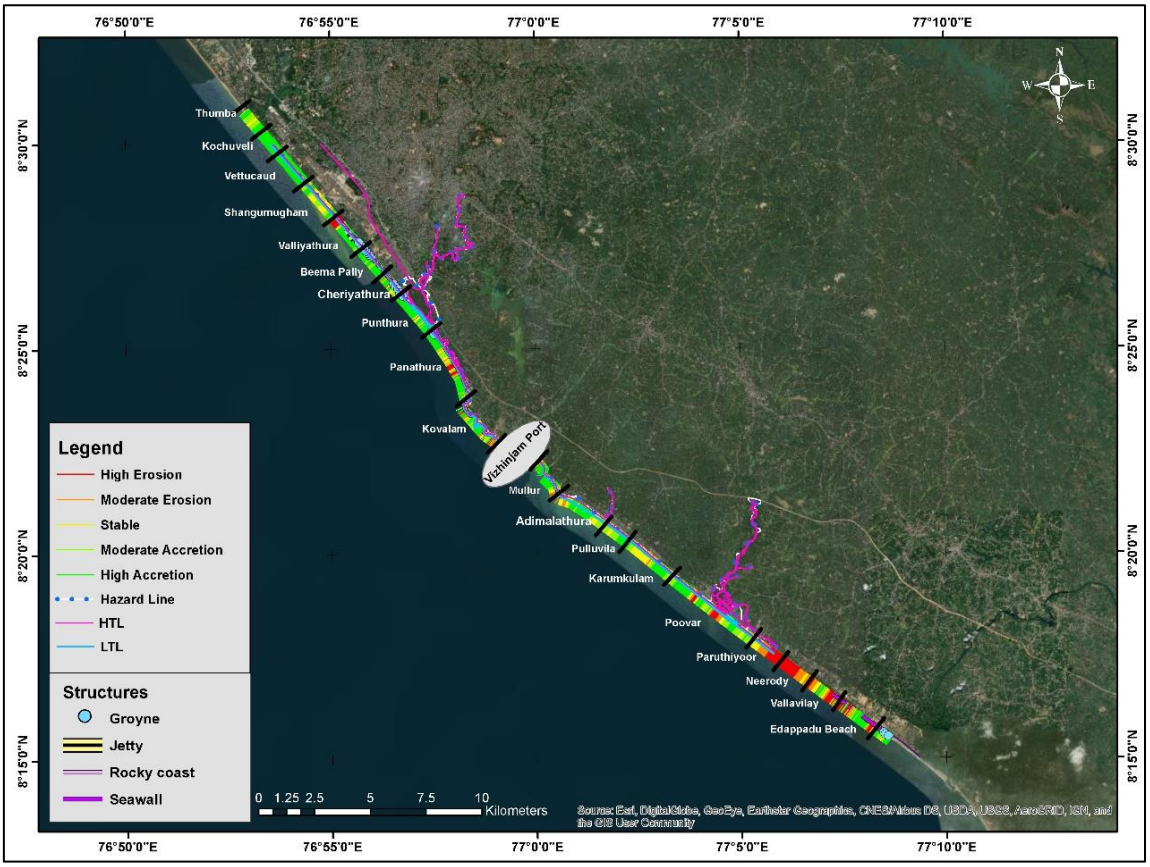


Figure 4.20 Shoreline Change Map - December 2018

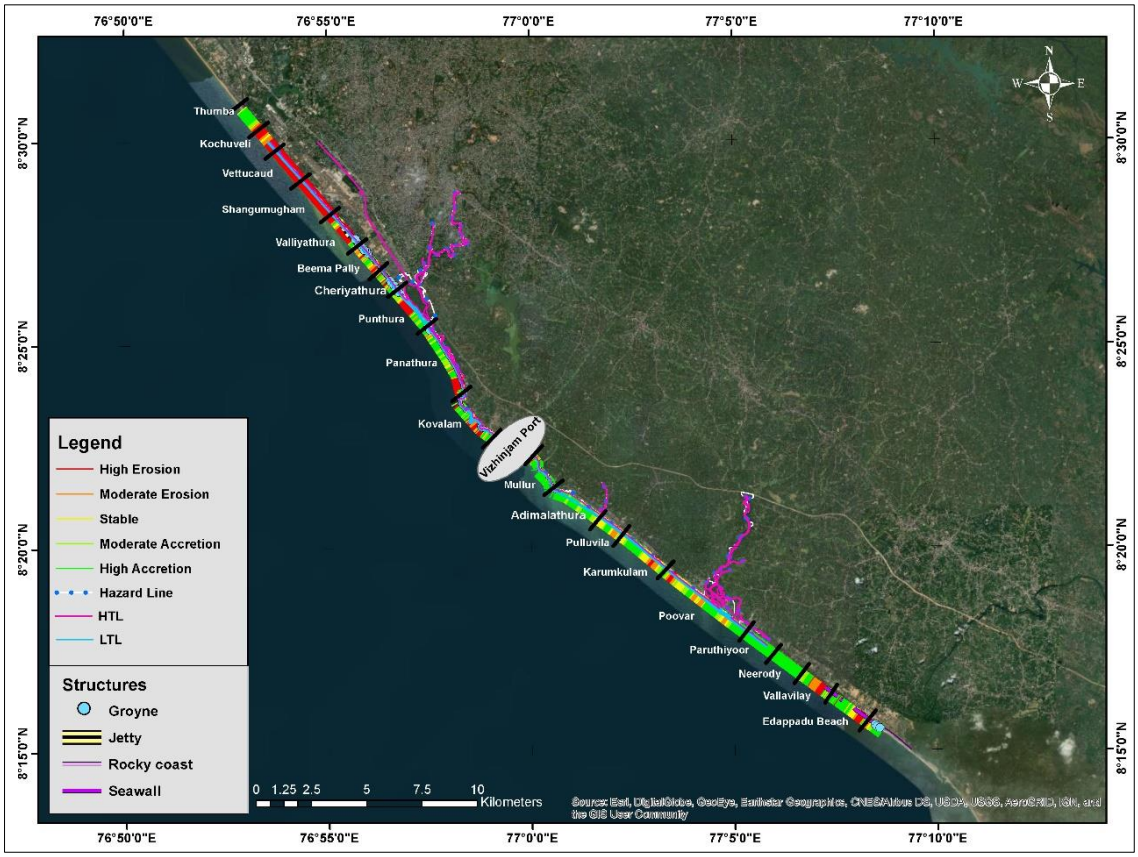


Figure 4.21 Shoreline Change Map - January 2019

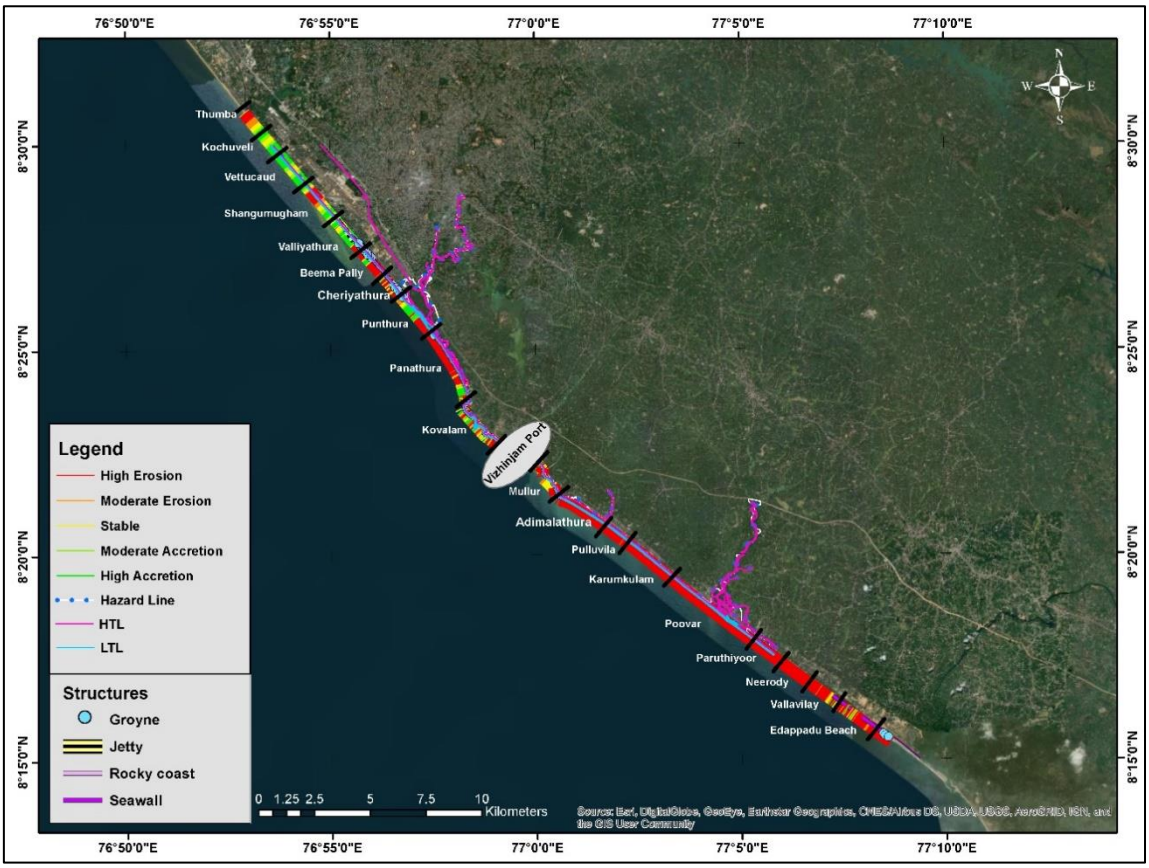


Figure 4.22 Shoreline Change Map - February 2019

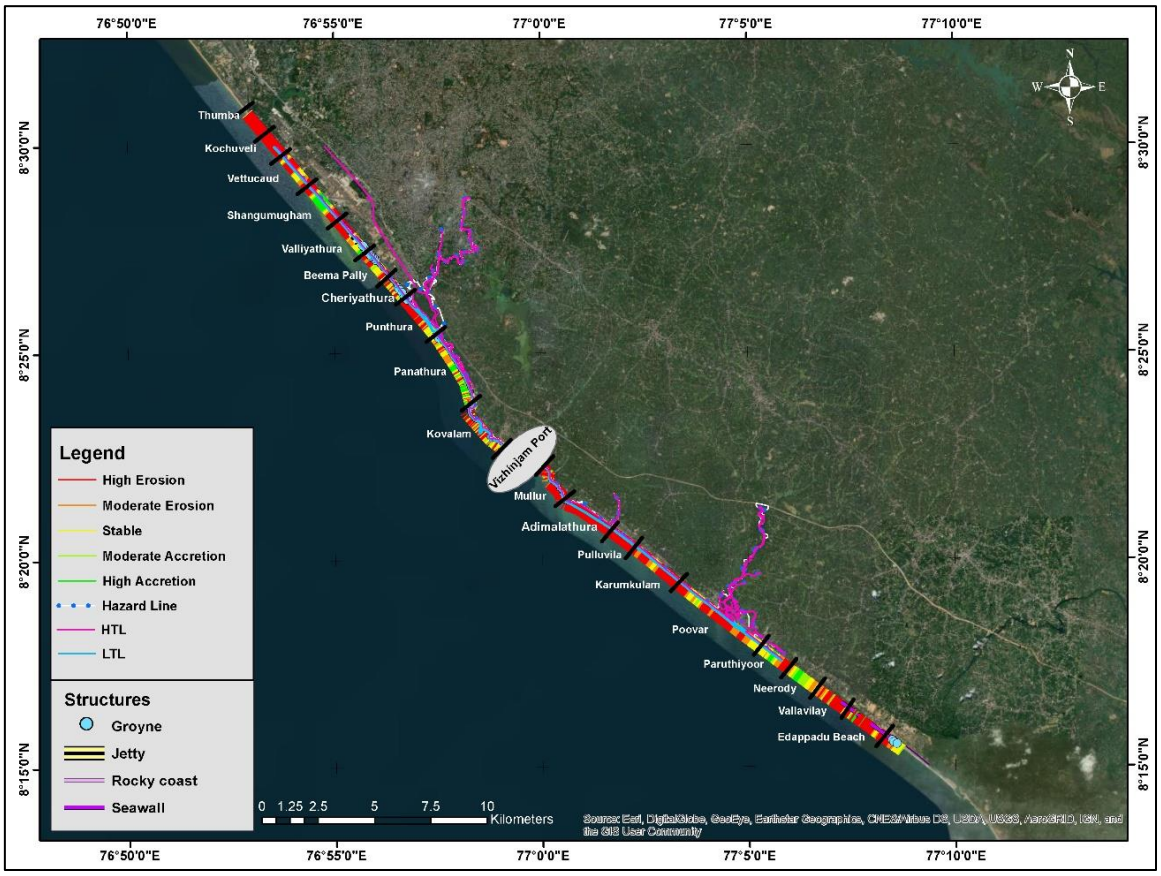


Figure 4.23 Shoreline Change Map - March 2019

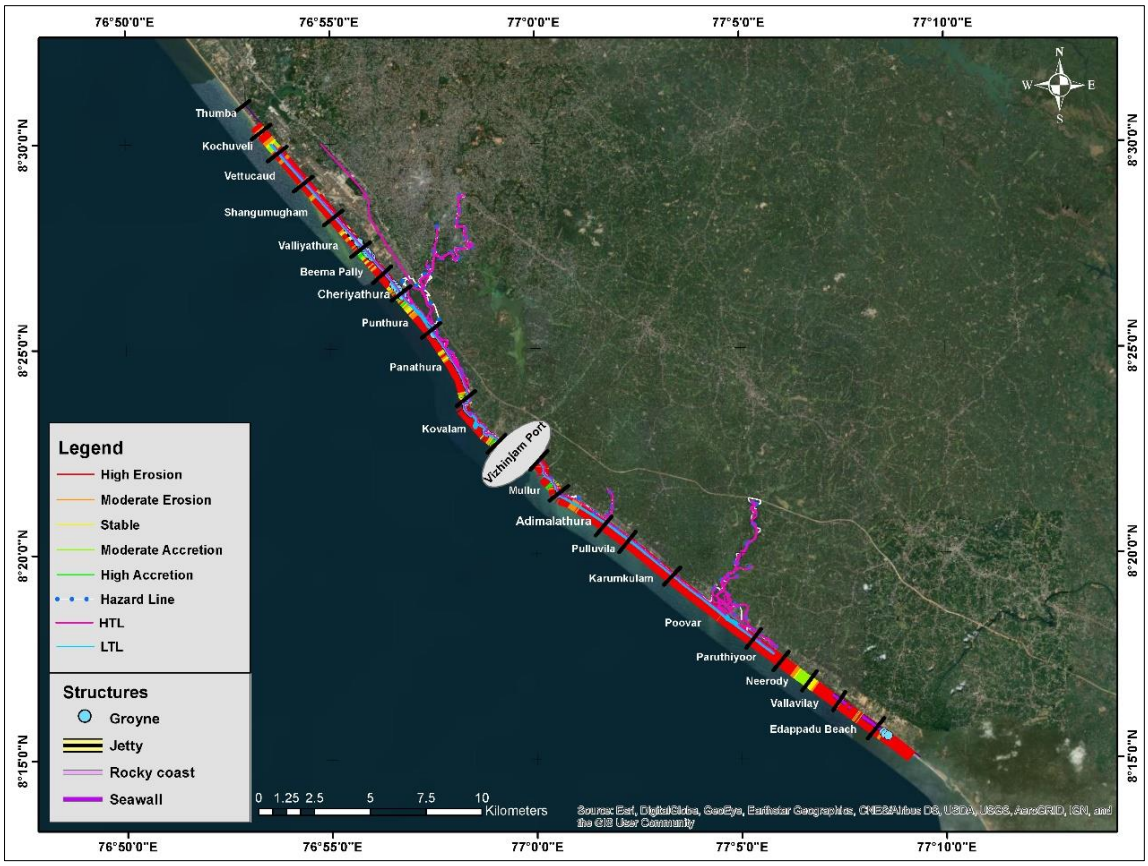


Figure 4.24 Shoreline Change Map - April 2019

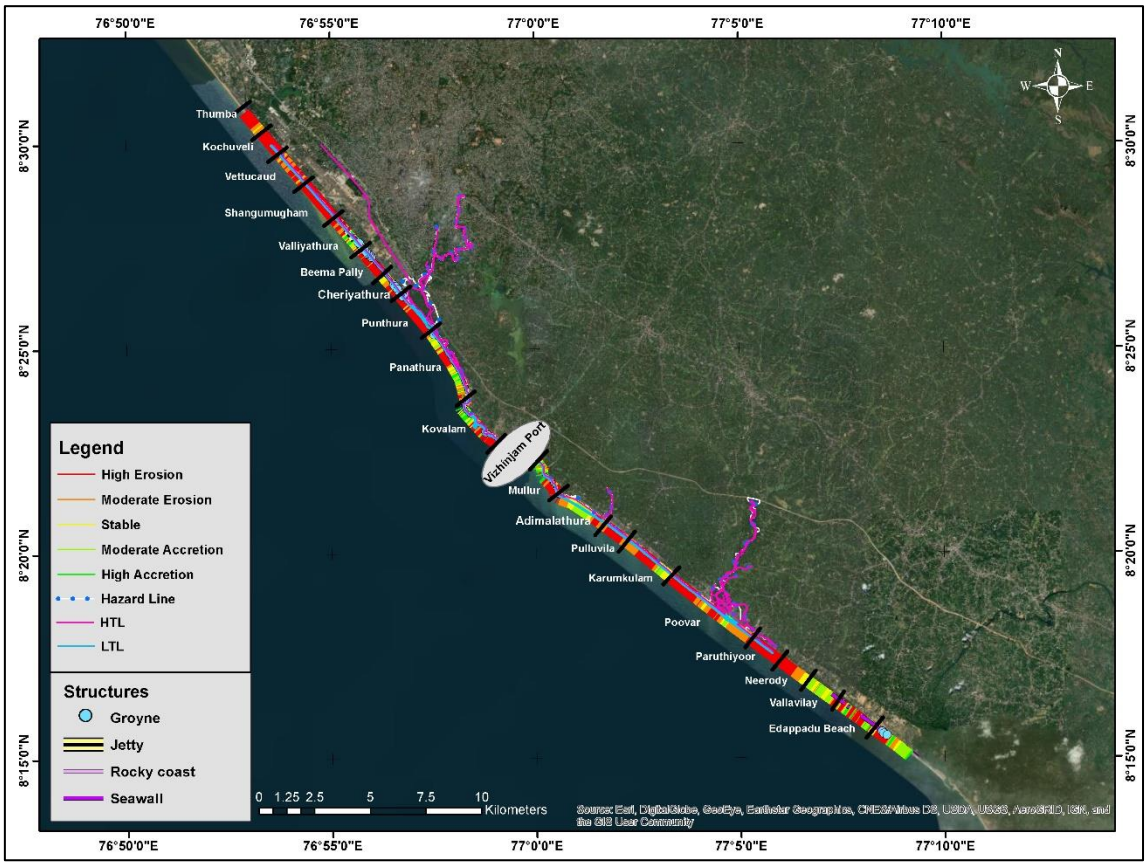


Figure 4.25 Shoreline Change Map - May 2019

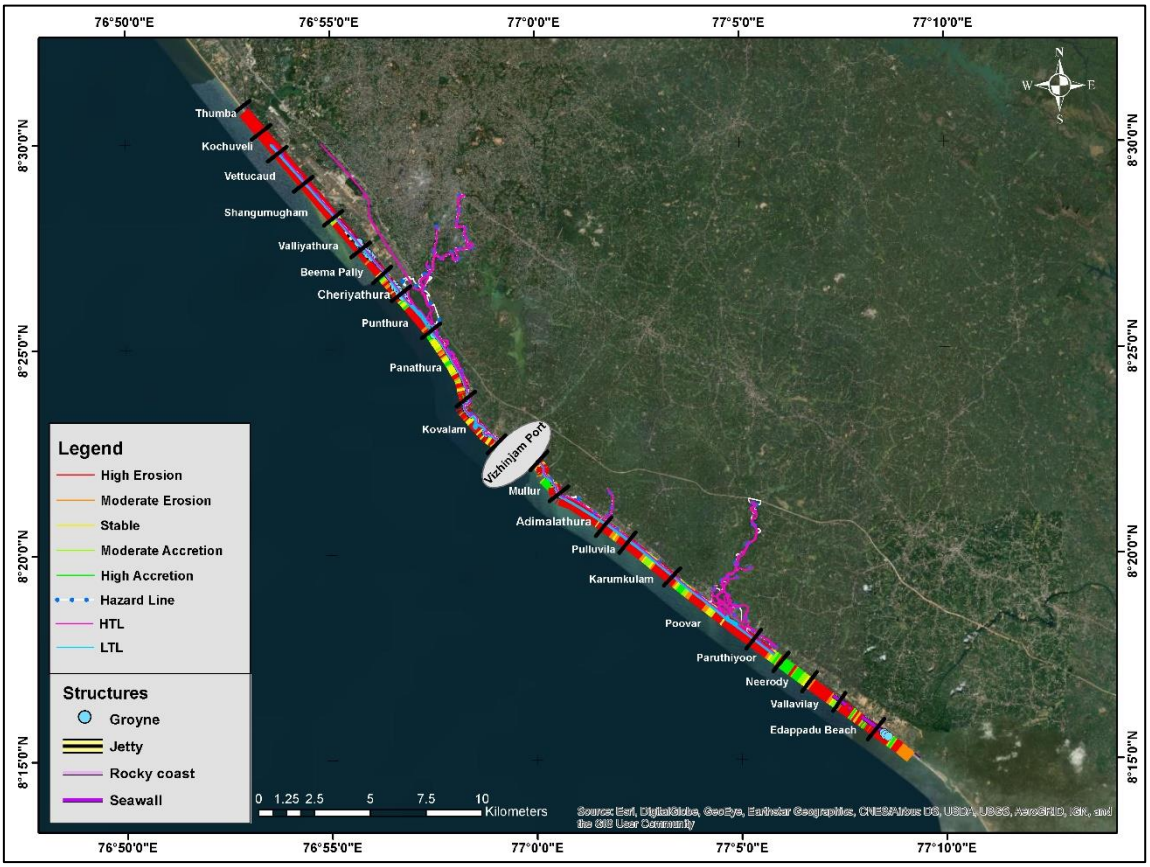


Figure 4.26 Shoreline Change Map - June 2019

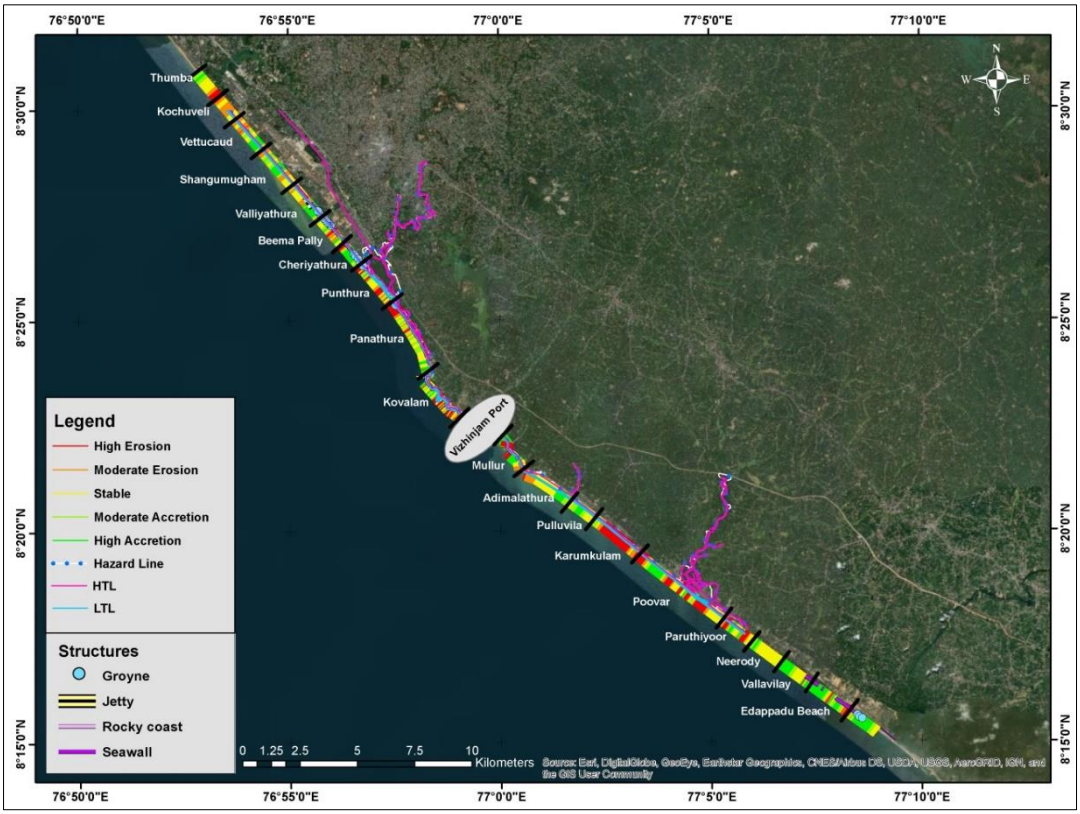


Figure 4.27 Shoreline Change Map – July 2019

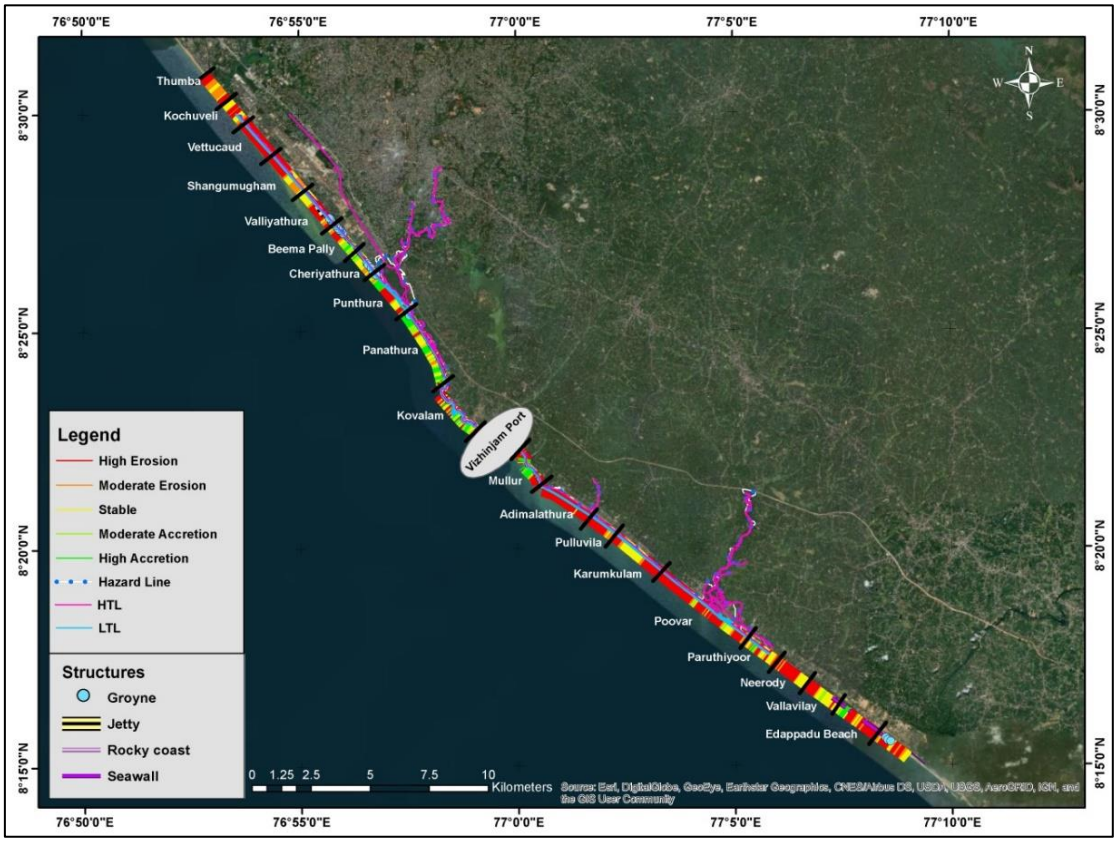


Figure 4.28 Shoreline Change Map - August 2019

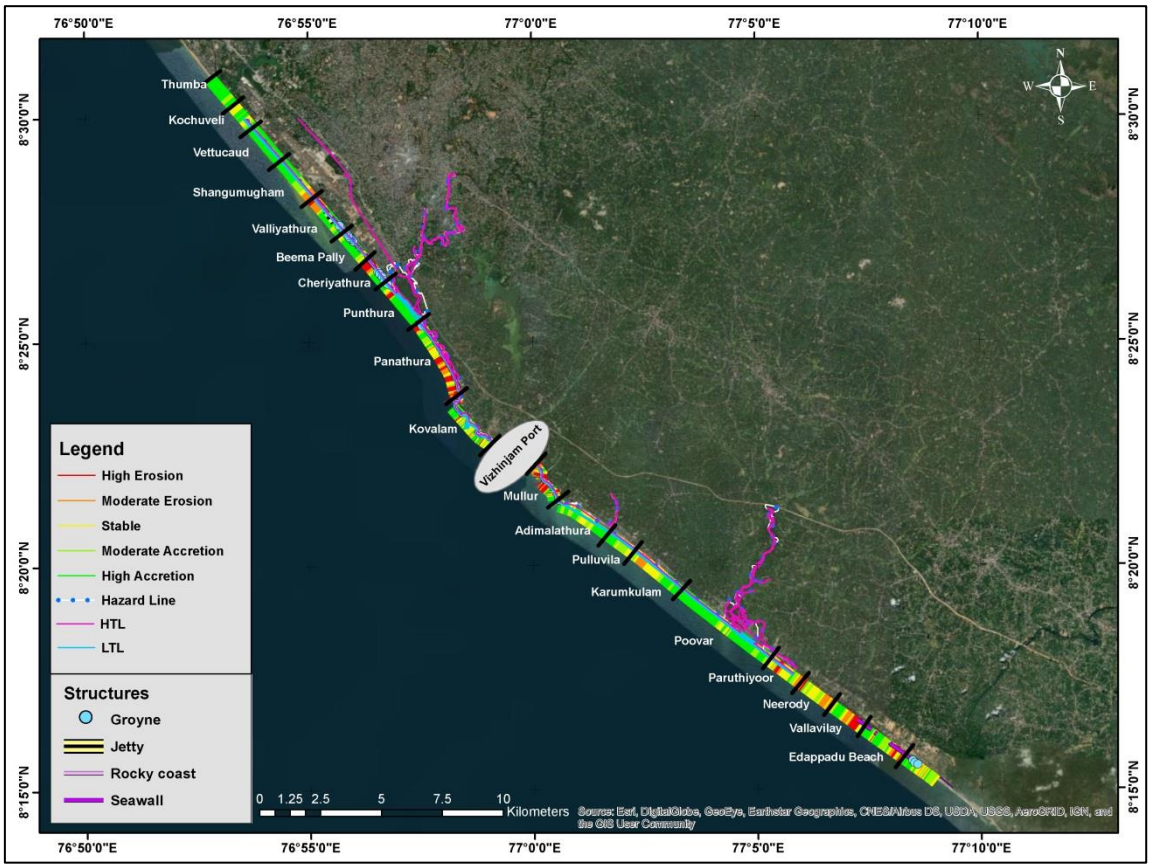


Figure 4.29 Shoreline Change Map - September 2019

4.2.2 Seasonal Shoreline Change from October 2018 to September 2019

As suggested by the shoreline and expert committee meeting held during 12th and 13th February 2019, the seasonal pattern has been followed in this report as Post monsoon (October-November 2018) Fair weather period (December 2018-March 2019), Pre-monsoon (April-May 2019) and Monsoon (June – September 2019).

4.2.2.1 *Results for Shoreline Change in Post Monsoon 2018 (October-November 2018)*

The seasonal shoreline change analysis for the post monsoon period 2018 is shown in Figure 4.30. The post monsoon period (October to November 2018) indicates net accretion along the Vizhinjam coast except high erosion spots at Valliyathura, Beemapally, Pannathura, and few transects at Mullur and Edapadu beach.

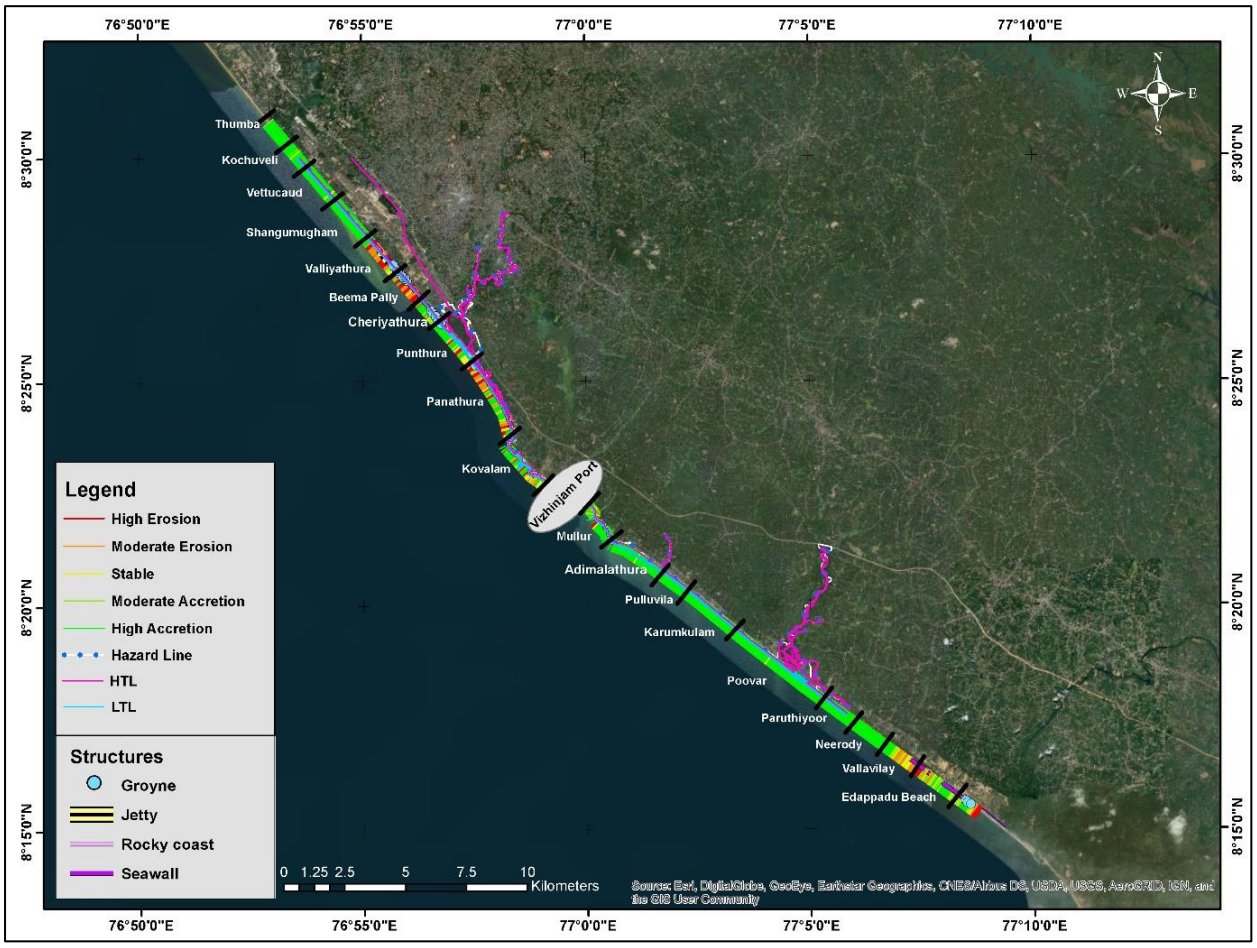


Figure 4.30 Shoreline Change Map – Post Monsson 2018

4.2.2.2 *Results for Shoreline Change in Fair Weather Period 2019 (December 2018-March 2019)*

The seasonal shoreline change analysis for the fair weather period 2019 is shown in Figure 4.31. The fair weather period (December 2018 to March 2019) indicates net erosion along the Vizhinjam coast except very few transects at Kovalam, Mullur and Edapadu beach.

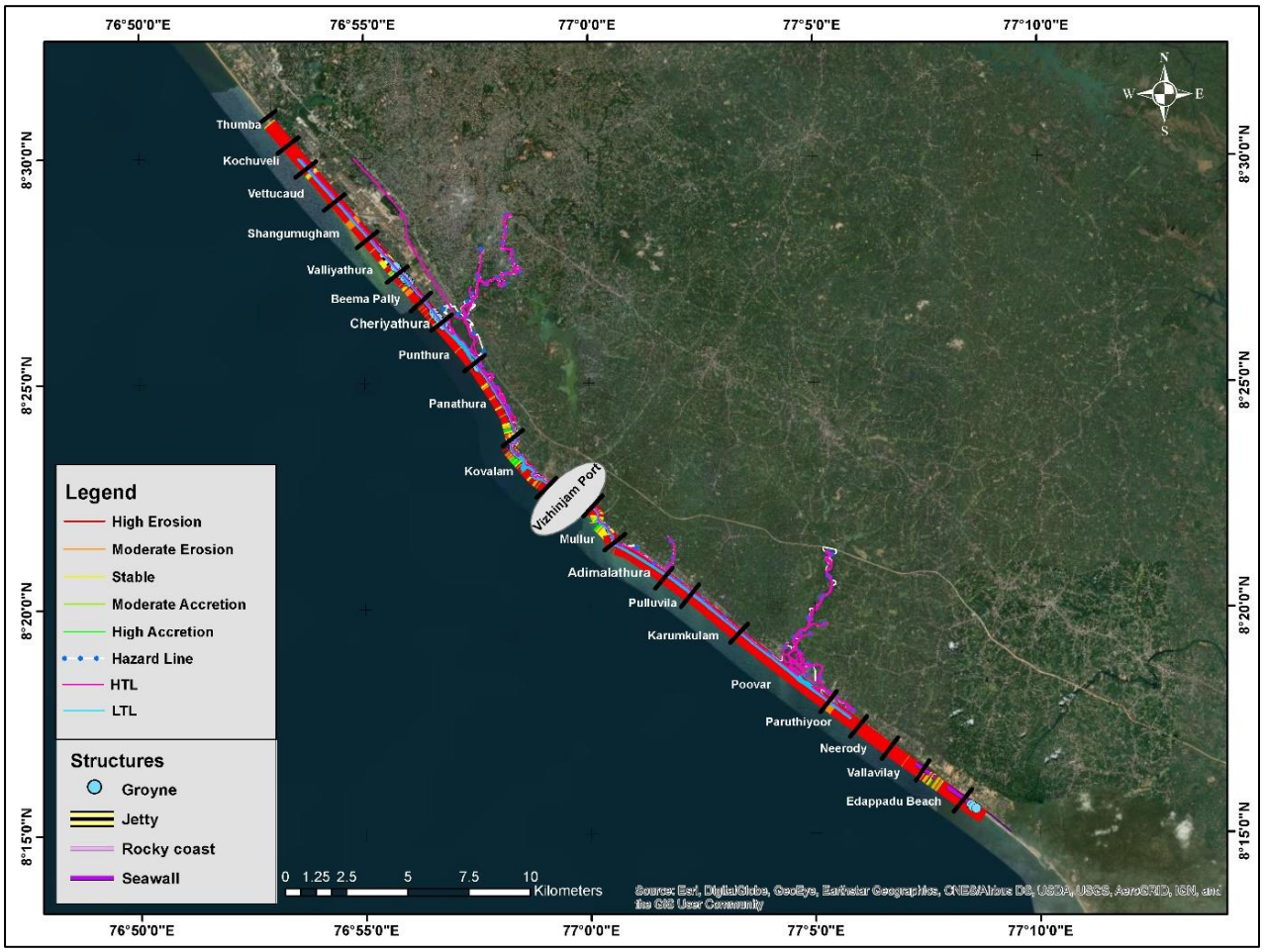


Figure 4.31 Shoreline Change Map – Fair Weather Period 2019

4.2.2.3 *Results for Shoreline Change in Pre-Monsoon Period 2019 (April 2019-May 2019)*

The seasonal shoreline change analysis for the pre-monsoon period 2019 is shown in Figure 4.32. The fair weather period (April 2019 to May 2019) indicates net erosion along the Vizhinjam coast except few transects at Valliyathura, Punthura, Pannathura, Kovalam, Mullur, Adimalathura, Karumkulam, Vallavilai and Edapadu beach.

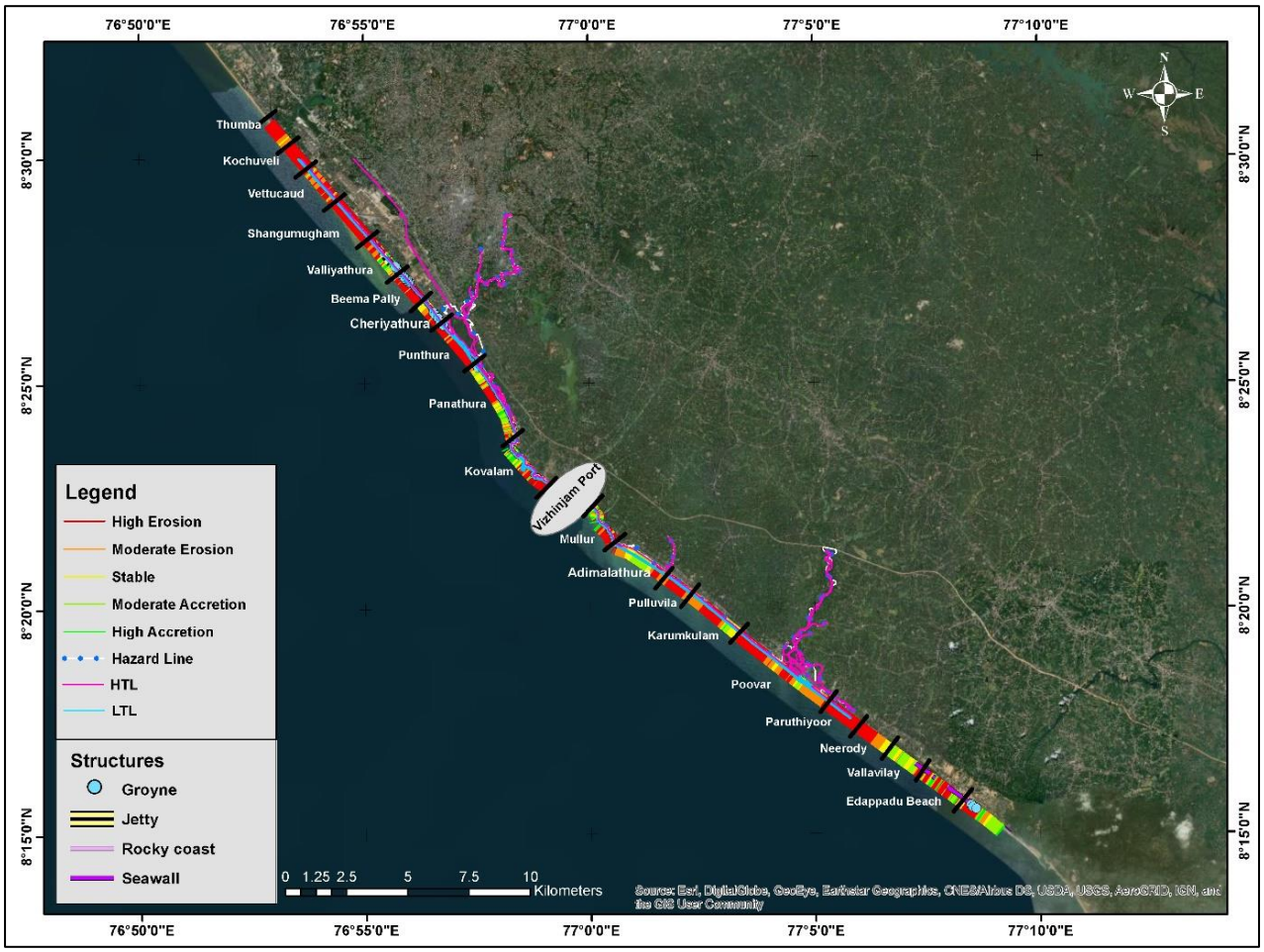


Figure 4.32 Shoreline Change Map – Pre-Monsoon Period 2019

4.2.2.4 *Results for Shoreline Change in Monsoon Period 2019 (June 2019-September 2019)*

The seasonal shoreline change analysis for the monsoon period 2019 is shown in Figure 4.33. The fair weather period (June 2019 to September 2019) indicates net accretion along the Vizhinjam coast except very few transects at Kochuvelli, Vettucaud, Valliyathura, Mullur, Adimalathura, Pullavila, Karumkulam, Paruthiyoor and Neerody.

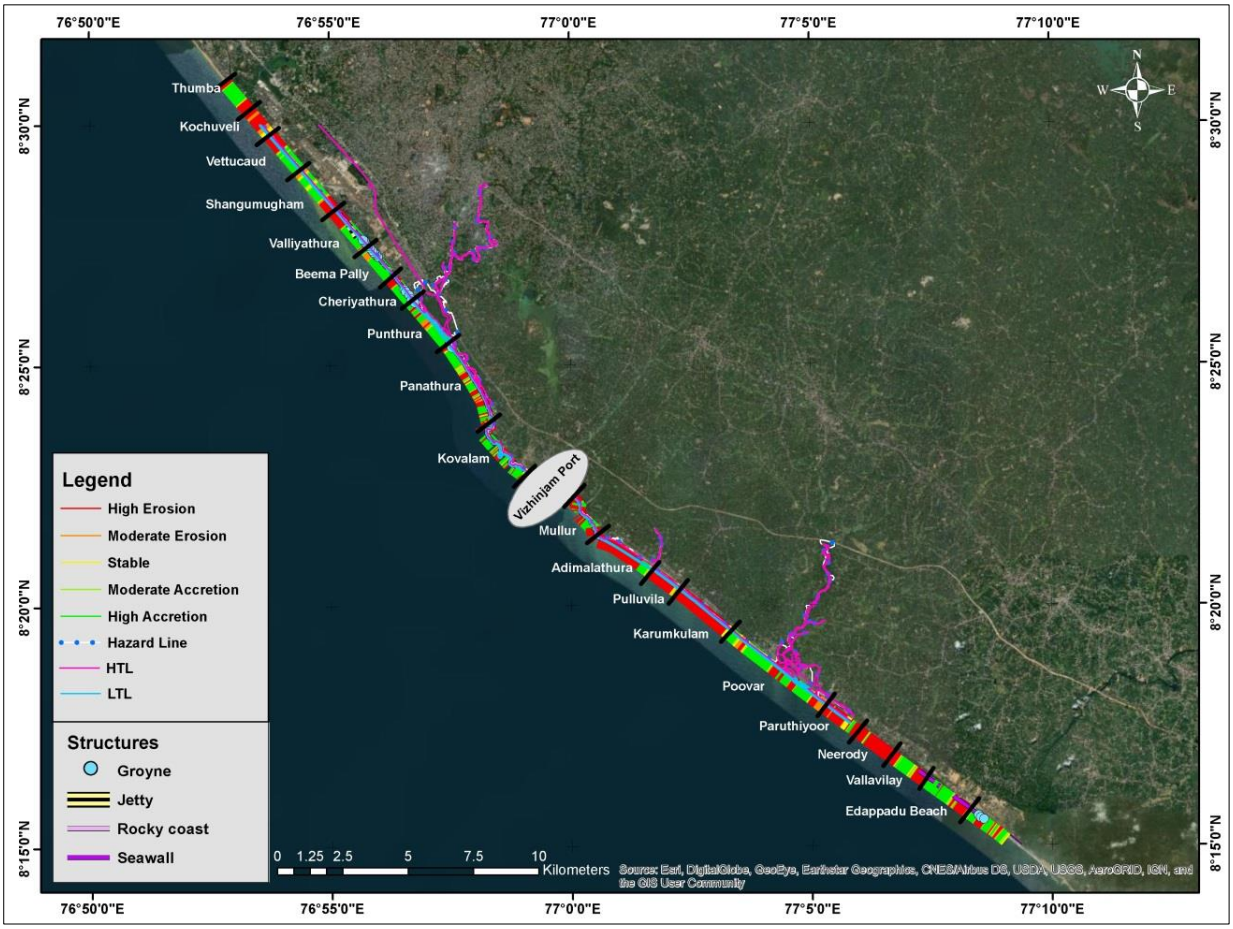


Figure 4.33 Shoreline Change Map – Monsoon Period 2019

4.2.3 Overall Shoreline Change from October 2018 to September 2019

Using high resolution satellite images (5m and 10m spatial resolution), the result has been processed for the period October 2018 to September 2019. Figure 4.34 shows the shoreline change map from October 2018 to September 2019. Few transects of Cheriyathura and Mullur indicates accretion, Pannathura and Adimalathura shows stable whereas erosion is noticed at Kochuveli, Shangumugam, Valliyathura, Punthura, Pullavila to Edapadu beach during overall shoreline analysis.

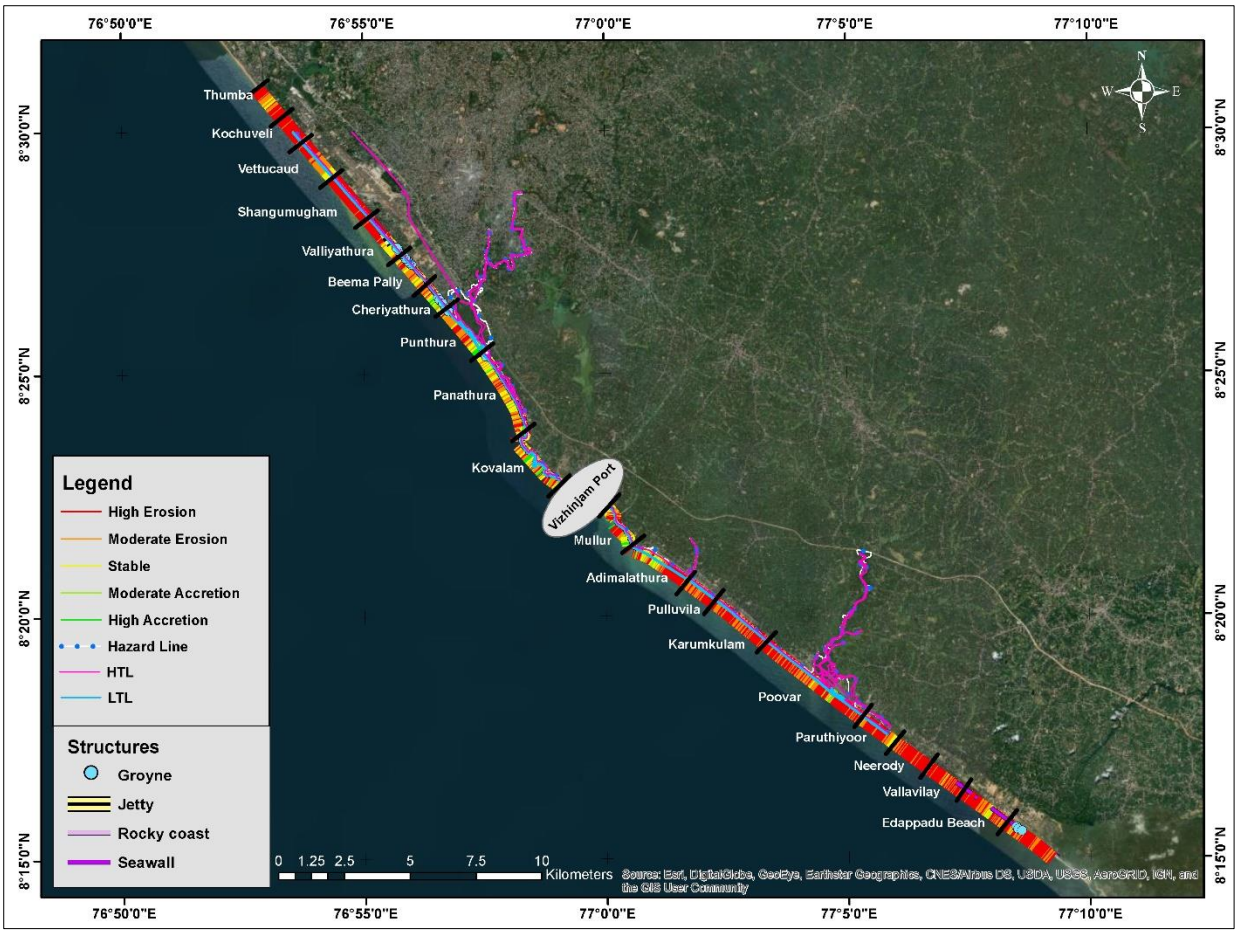


Figure 4.34 Overall Shoreline Change Map October 2018 to September 2019

4.2.4 Seasonal Shoreline Change comparison between 2017-2018 and 2018-2019

October 2017 and October 2018 (Post Monsoon period)

The shoreline change between October 2017 and October 2018 is shown in Figure 4.35. It indicates accretion at Beemapaally, Cheriyathura, Punthura, Pannathura, Kovalam and Edapadu beach whereas erosion at Vettucaud, Shangumugham, Valliyathura, Mullur to Neerody.

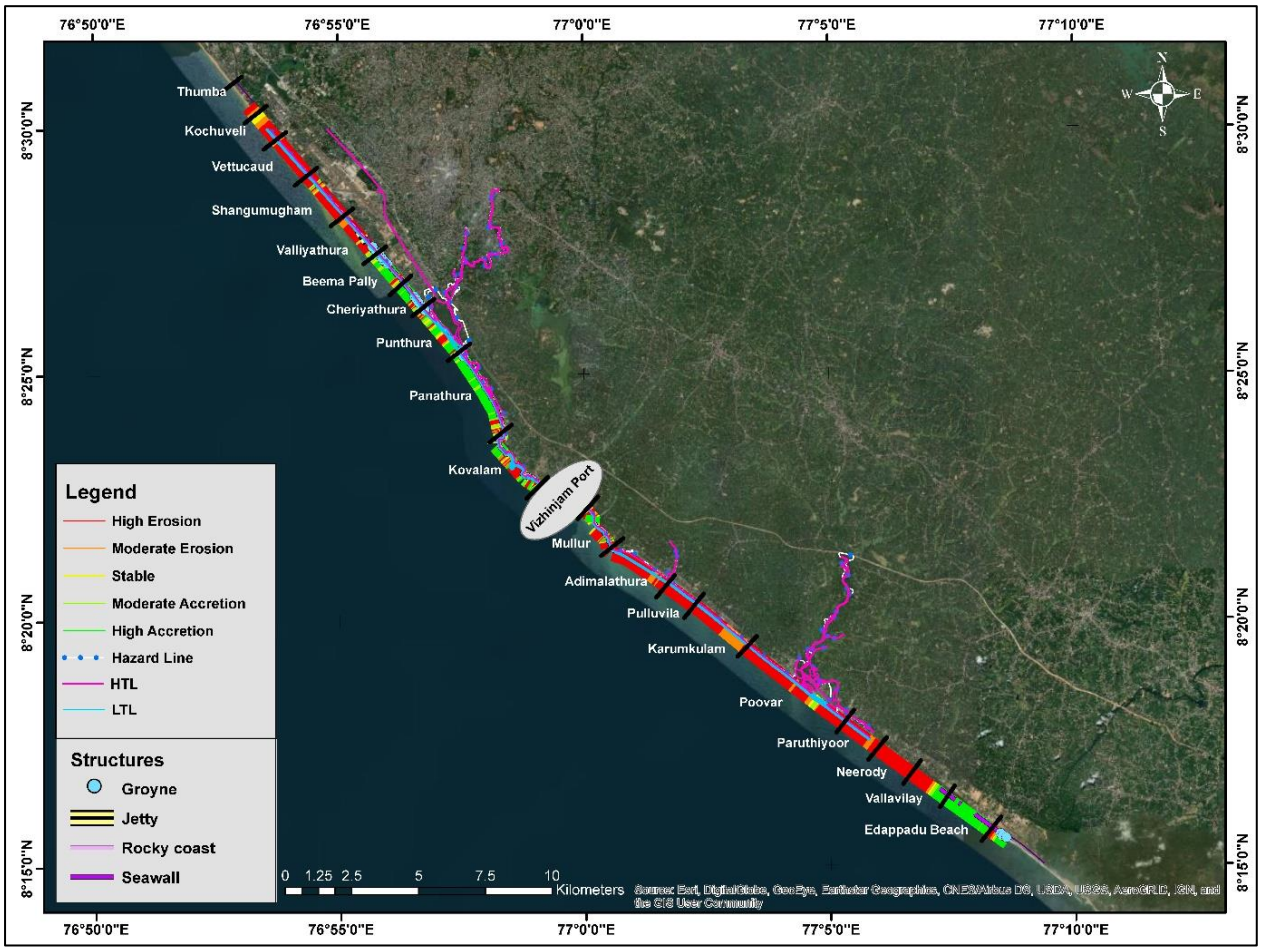


Figure 4.35 Shoreline Change Map October 2017 and October 2018

February 2018 and February 2019 (Fair weather period)

The shoreline change between February 2018 and February 2019 is shown in Figure 4.36. It indicates accretion at Beemapally, Cheriyathura, Punthura, Pannathura, Kovalam and Edapadu beach whereas erosion at Vettucaud, Shangumugham, Valliyathura, Mullur to Neerody.

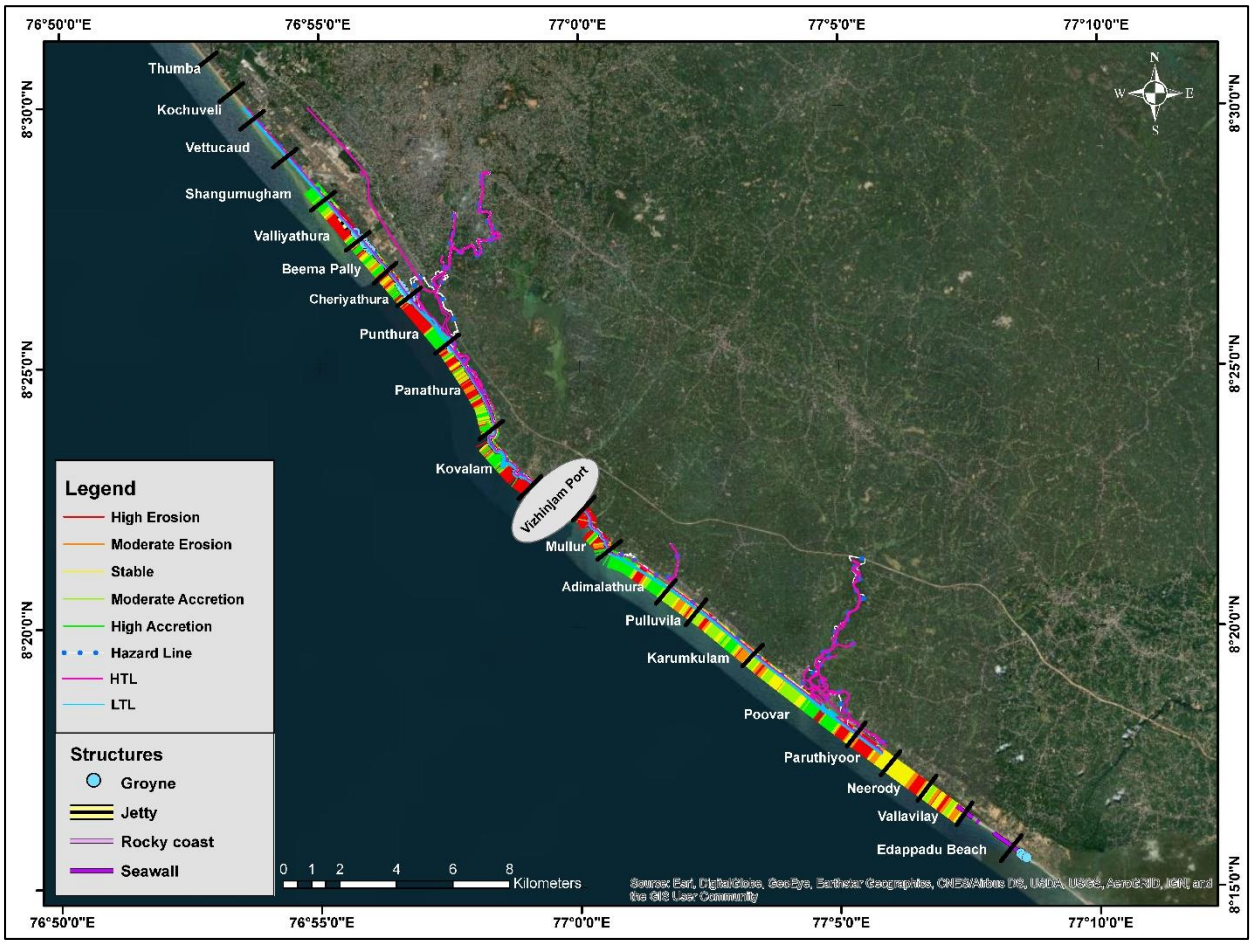


Figure 4.36 Shoreline Change Map February 2018 and February 2019

April 2018 and April 2019 (Pre-Monsoon period)

The satellite image for the April/May 2018 is not available without cloud cover. Hence, the comparison for the pre-monsoon period 2019 with the pre-monsoon period 2018 has not been carried out.

September 2018 and September 2019 (Monsoon period)

The result has been processed for the period September 2018 to September 2019. Figure 4.37 shows the shoreline change map from September 2018 to September 2019. High erosion is noticed at Kochuveli, Shangumugam, Valliyathura, Punthura, Pullavila to Edapadu beach and accretion at Cheriyathura and Adimalathura.

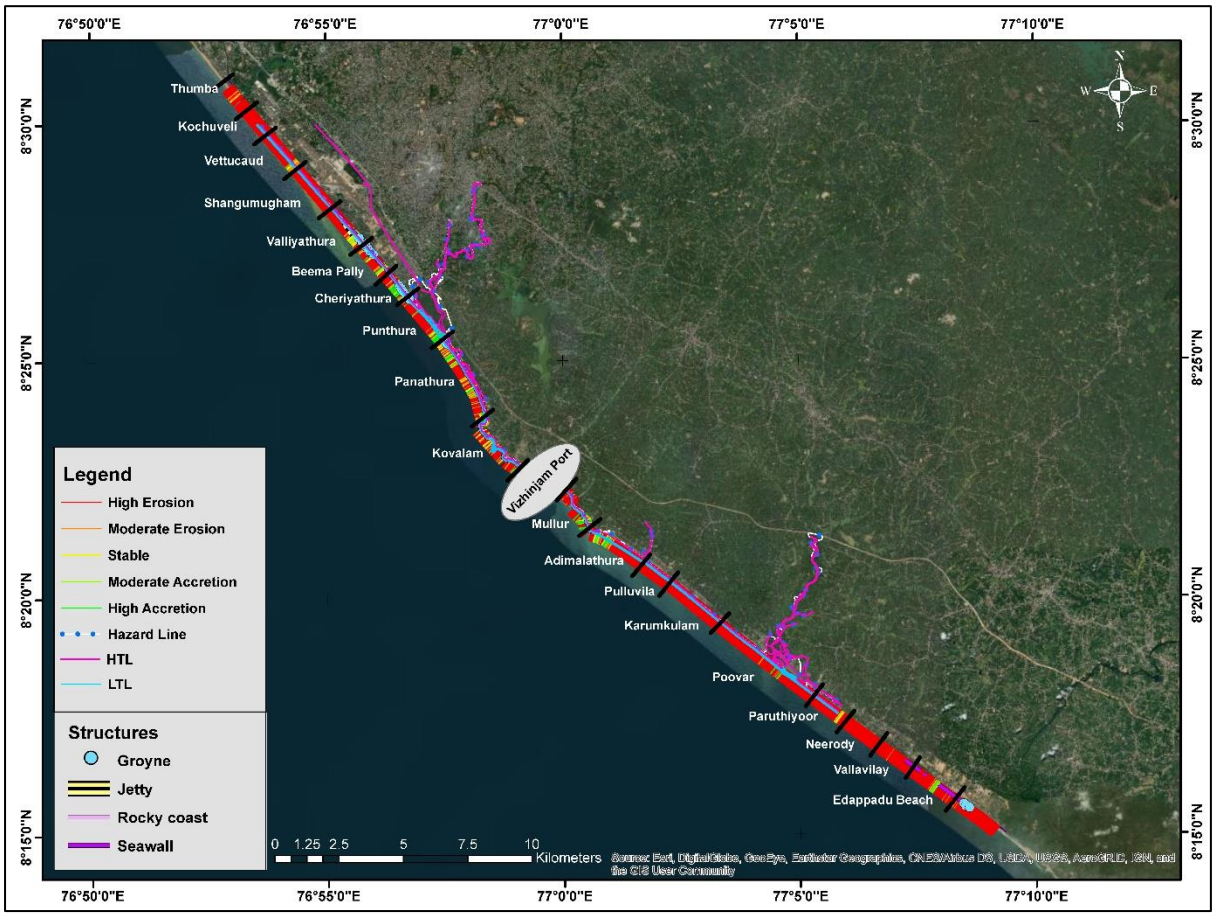


Figure 4.37 Shoreline Change Map September 2018 and September 2019

4.2.5 Shoreline Change comparison between January 2015 and February 2019

The comparison of January 2015 shoreline with February 2019 using high resolution satellite images has been presented in the Figure 4.38. The comparison shows erosion at Vettucaud to Valliyathura, Punthura and Vallavilay while Beemapally, Kovalam, Mullur, Adimalathura and Edapadu beach shows accretion.

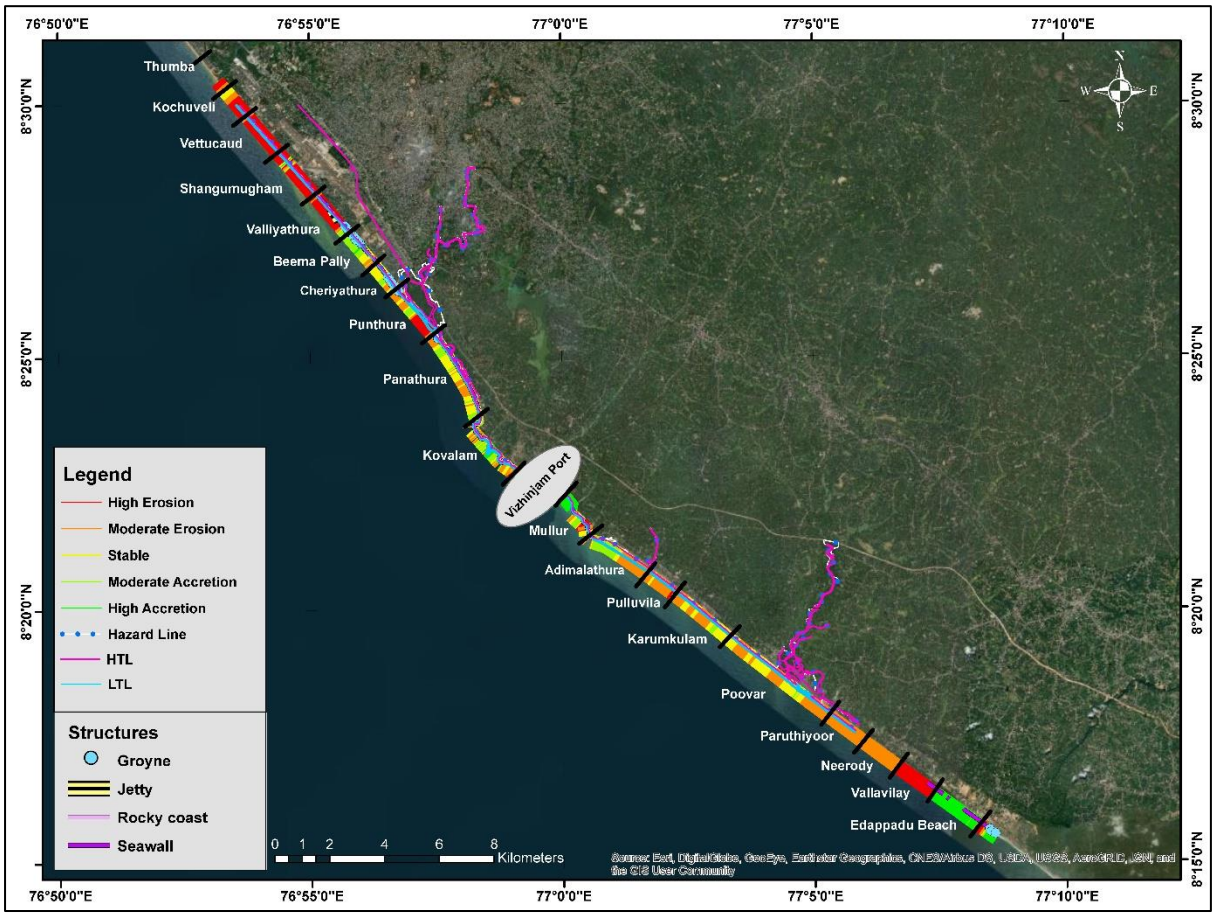


Figure 4.38 Shoreline Change Map- January 2015 to February 2019

4.3 Validation and Comparison of results

For the validation of the results from the shoreline derived from the satellite images of different spatial resolution (PAN (2.5m), LISS 4 (5m) and MSI (10m)) has been compared shown in Figure 4.39. The transect numbers indicate the 30m interval along the 40km stretch from Thumba to Edapadu beach (1350 number of transects). The comparison shows that the error in extraction of shoreline from 10m Sentinel images is 4.65m while the error from 5m satellite image is 2.75m when compared with the shoreline derived from 2.5m satellite images. The error in extracting the shoreline from satellite images reduces with respect to the spatial resolution of the satellite images.

It can be noted that the result from the two analysis (high resolution satellite image and beach profile data) shows concurrence. The difference in the shoreline distance along the transects south of Vizhinjam port is due to the fact that the beach profile data has been collected at different time and date whereas the satellite image captures the entire coast at a single time and date.

The field shoreline data collected by NIOT during September 2018 using DGPS has been compared with shoreline derived from Beach profile (collected by Surveying agency) and satellite imagery is shown in Figure 4.40. With the higher resolution satellite images, the field shoreline exactly matches with the shoreline derived from the satellite images whereas shoreline derived from the beach profile matches at every 500m.

As suggested in the shoreline committee dated 5th September 2019, the LTL, HTL and Hazard line has been demarcated on the shoreline maps provided in this report. Also, the graph shown in Figure 4.40 compares the shoreline derived from 5m and 10m satellite images, beach profile data, LTL, Hazard line with the field collected shoreline data specific to the stretch from Shangumugham to Punthura.

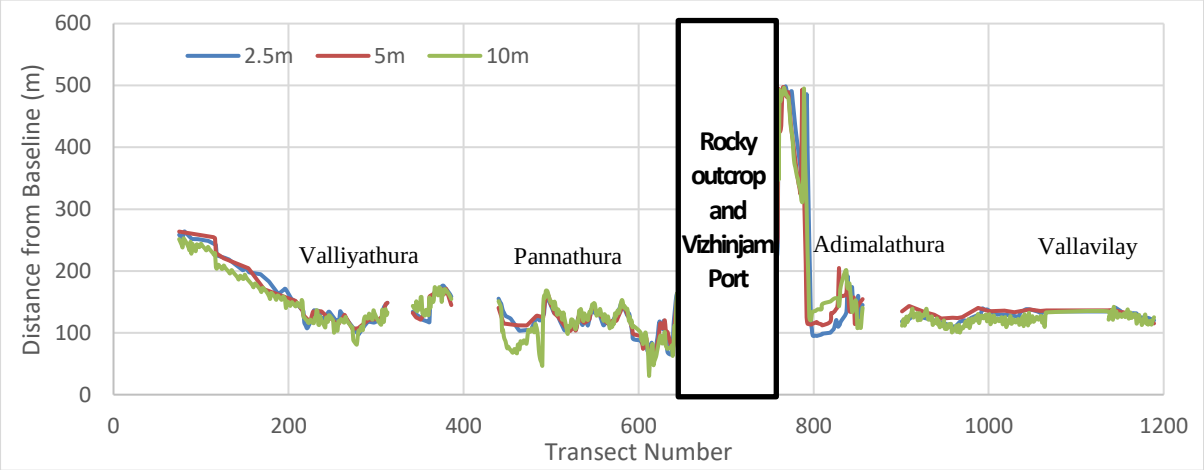


Figure 4.39 Comparison of Shoreline data from satellite images of different spatial resolution and beach profile data with field shoreline

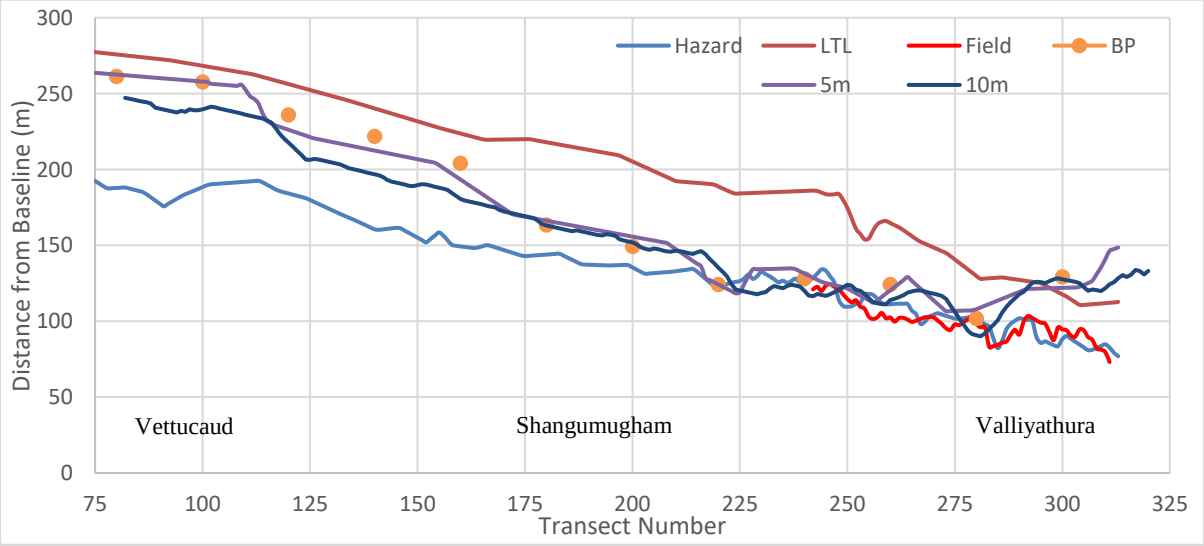


Figure 4.40 Comparison of Shoreline data from satellite images of different spatial resolution, beach profile data, LTL, Hazard line with field shoreline from Vettucaud to Valliyathura

The comparison of the erosion spots from the previous annual report October 2017-September 2018 for the shoreline change analysis for the years 2000-2005, 2005-2010, 2010-2015, 2015-2018 has been compared with the results of 2018-2019 shown in Table 4.3. It can be noted that the spots of erosion such as Valliyathura, Shangumugham and Punthura remains same before the commencement of the port (December 2015).

Moreover, periodic long period swell with high energy waves and tidal flooding creates beach erosion at these sites. Sanil Kumar et al, 2018 have discussed the increase in the significant wave height on western shelf seas (~1.2m) than the eastern shelf seas (~1.0m) in the last decade due to stronger influence of summer monsoon in the Arabian sea compared to Bay of Bengal which plays an important role in the beach sediment transport.

Table 4.3 Comparison of Erosion spots since 2000 using high resolution satellite images

<table>
<tr><th rowspan="8">Erosion spots</th><th>2000-2005</th><th>2005-2010</th><th>2010-2015</th><th>2015-2018</th><th>2015-2019</th><th>2018-2019</th></tr>
<tr><td colspan="5">No data to the north of Shangumugham</td><td>Kochuveli</td></tr>
<tr><td>Shangumugham</td><td rowspan="4">Valliyathura</td><td>Shangumugham</td><td rowspan="2">Valliyathura</td><td rowspan="2">Valliyathura</td><td>Shangumugham</td></tr>
<tr><td>Valliyathura</td><td>Valliyathura</td><td>Valliyathura</td></tr>
<tr><td>Punthura</td><td>Punthura</td><td>Punthura</td><td>Punthura</td><td>Punthura</td></tr>
<tr><td rowspan="2">Pullavila</td><td>Pannathura</td><td rowspan="2"></td><td rowspan="2">Pullavila to Edapadu</td><td rowspan="2">Pullavila to Edapadu</td></tr>
<tr><td>Poovar to Neerody</td></tr>
</table>

5 VETTING OF REPORTS/ DATA

Periodical (monthly, seasonal and yearly) reports on field data quality check and data on water quality, sediments, shoreline monitoring, etc. are scrutinized by NIOT. The Oceanographic and bathymetric data received from AVPPL for the year 2018-2019 are listed in tables 5.1. Sediment samples were collected at the cross-shore profile locations seasonally. Water quality (turbidity, TSS and salinity being carried out at 4 locations, two each north and south of Vizhinjam port).

Vetting of Reports on oceanographic and bathymetric data collection for assessment of Shoreline changes has been completed till September 2019. Recently a vetting of Data analysis and Model studies for Vizhinjam Port using data collected by AVPPL (March 2018 to February 2019) by LNTIEL has been completed during November 2019.

Table 5.1 Data Status October 2018 to September 2019

Sl no.	Parameters	Post monsoon (Oct-Nov 2018)		Fair weather (Dec 2018-Mar 2019)				Pre monsoon (Apr-May 2019)		Monsoon (Jun 2019-Sep 2019)			
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep
1	Wave (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	Tide (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	Met (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4	ADCP (4 locations) at 20 m water depth	✓(December 2018)						✓ (May 2019)		✓(Sep 2019)			
5	Bathymetry	✓(December 2018)						✓(May 2019)					
6	Beach Profile (81 locations at 500 m distance)	✓	✓	✓	✓	✓	✓	✓	✓	Onshore Profiles	Onshore Profiles	Onshore Profiles	✓
7	Turbidity	✓	✓	✓	✓	✓	✓	✓	✓	Due to change in contractor and due to rough sea conditions, the turbidity buoys were not deployed from 01.06.2019 till 30.09.2019			
8	River bathymetry (7 locations)	✓ (July 2019)											
9	Water sample (TSS, Salinity and temp)	✓(Dec 2018)						✓(May 2019)		✓(Sep 2019)			
10	Grain size (81 locations at 500 m distance)	✓(Beach Sediment Sample - Nov 2018)		✓(Feb 2019)				✓(May 2019)		✓(Sep 2019)			
11	LEO (81 locations at 500 m distance)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

5.1 Methodology adopted for verifying various monitored data

The calibrated pressure sensor was installed at Vizhinjam port. The Vizhinjam tide gauge data has been connected to bench mark near jetty and the data were observed with respect to chart datum. NIOT has checked the consistency of water level by installing radar level sensor near to the existing tide gauge. The periodic check by manual measurement logs are also verified and the difference matched well within the acceptable limit. The observed tide data are checked thoroughly and suspicious data like spikes are flagged/removed.

The beach profile data quality check has been carried out based on the quantity of the data received against the temporary bench mark and beach profile comparison with the earlier data sets. The data set has been discarded from the analysis based on the following criteria:

1. No simultaneous offshore profile data with onshore profile observed less than +1 m contour.
2. More than 50% spatial profile deviation from the previous month data with respective to x and y coordinates
3. Data set which has less than 4 data points
4. The cross sectional profiles survey has been carried out using RTK method. The NIOT team members visited site during RTK survey and checked the base station and rover

setup during survey. The consistency of position and level before starting the survey and after finishing survey has been checked during survey.

Initial data quality analysis has been done based on the above criteria. When two of the above points are noticed in all the profile data in a month, the data of that particular month has been discarded.

Sudden unrealistic changes/Spikes observed in the profile level arising due to some reasons are carefully examined and removed before the analysis. Further to normalize the gaps in a single profile bilinear interpolation has been carried out to fill the data gaps and uniform 1 meter interval profile data has been generated. Shoreline and Nearshore Data System (SANDS) that was used in the analysis has its own Data Quality procedure which will not allow the system to proceed and analyze the data but ends up with error. All profiles are manually checked before entering the data in to SANDS.

The calibration of multi-beam echo sounder commonly referred as patch test. It is required to identify the offsets which would be applied to the data in order to compensate any misalignment in various sensors used. The offsets from vessel reference point, DGPS antenna and transducer was measured and entered into the acquisition software with in-situ measurement of sound velocity profiler. NIOT has instructed to AVPPL for carrying out the crossline survey as per the IHO standards for multi-beam survey. The NIOT team has checked patch test and other offsets for bathymetry survey.

TSS data provided was analyzed was verified using the protocol prescribed by the American Public Health Association (APHA) 21st Edition 2540 D and also validated using available data. Turbidity was measured using turbidity meter as per APHA protocol. The instrument was calibrated using formazin / factory calibrated standard.

The ADCP current data analyzed using standard oceanographic methods and analysis techniques by the software being used by the surveying agency. These includes standard visualization techniques, pre and post calibration at lab, time-series and statistical methods and numerical analysis. The ADCP quality control checks, correlation test, false target rejection test and error velocity test.

The data copied at buoy internal memory was downloaded at the end of retrieval and verified against the real-time data for any missing part. Wave data was processed using the

manufacturer's software package after downloading to the field PC. Wave parameters like Significant wave height, period, maximum wave height and wave direction was tabulated against time. Data gaps, Spikes or improbable data was verified and removed. As the present used directional wave rider buoy is working based on the GPS principle, hence calibration of the buoy is not required.

Grab samples analysis report checked whether i) Grain size analysis is carried out as per IS 2720 PART IV, ii) Grain size distribution chart and table are provided as per IS 2720 PART IV, Appendix A, iii) Soil classification is carried out as per IS 1498 and iv) D50 values and location are provided for each sample. Also, duplicate set of few samples are collected and analysed at NIOT Geotechnical laboratory for cross verification of results submitted.

6 CONCLUSION

NIOT has carried out shoreline analysis using available high resolution satellite images and analysis of beach profile data for October 2018 to September 2019. Apart from that NIOT has also vetted / reviewed project proposals, field measured data and reports on various oceanographic data related to port development and modeling report by LNTIEL.

The zones of High erosion and accretion have been derived from the available high resolution satellite images for the study period. Valliyathura, Punthura and Edapadu have been identified as zones of erosion, whereas Kottakal, Poovar and Karumkulam regions are identified as zones of accretion.

Beach profile analysis for the entire 40 km stretch has been carried out to estimate the monthly, seasonal and annual changes in the beach volume. The monthly analysis during the study period shows that the beach undergoes erosion during the months of February to September and beach formation from October to January with varying magnitude. The seasonal analysis shows fair weather period (January to March) exhibits stable to minor erosion, Pre-Monsoon (April-May) and Monsoon (June to September) exhibits erosion, while Post Monsoon (October to December) exhibits deposition. The seasonal analysis 2018-2019 compared with the seasonal analysis 2017-2018 indicates erosion during monsoon period.

The shorelines derived from the satellite images of different spatial resolution and beach profile has been compared with the shoreline collected from field. Further the analysis using

available high resolution satellite images has been extended with the monthly, seasonal and annual shoreline change analysis from October 2018 to September 2019. The zones of high erosion and accretion derived from the satellite images have been compared with the results from the beach volume change.

The comparison of the erosion spots from the shoreline change analysis (Annual Report 2017-2018) for the years 2000-2005, 2005-2010, 2010-2015, 2015-2018 has been compared with the results of 2018-2019. It can be noted that the spots of erosion such as Valliyathura, Shangumugham and Punthura remains same before and after the commencement of the port (December 2015).

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